# THE MAIN CURRENTS OF ZOÖLOGY

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PROFESSOR OF ZOÖLOGY IN NORTHWESTERN UNIVERSITY

NEW YORK

HENRY HOLT AND COMPANY

1918

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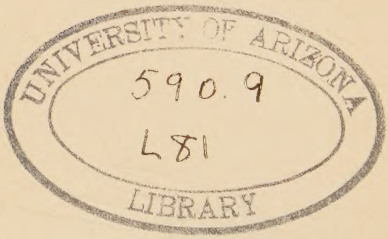

# PREFACE

THE conviction has been gradually forced upon the writer that persons who wish to get an insight into zoölogy as a science have difficulties in finding the necessary helps. The conventional treatise on zoölogy deals chiefly with facts about animals and certain phenomona of their lives, but omits a concurrent account of the results of zoölogical advances. In educational institutions, also, the method of using animal types as the sole background of knowledge, together with drill on the facts observed in the laboratory, has resulted in a one-sided and inadequate conception of zoölogy.

Zoölogical progress represents a stream of thought—not merely accretions of knowledge about animals. In order to comprehend zoölogy in the light of its progress it is necessary to trace its main currents; merely to accumulate a certain set of facts about animals will cause one ever to remain outside of the subject. It is well to remember also that the interpretations resulting from zoölogical observations have had great influence in liberating thought and on general intellectual advancement.



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It is the purpose of this volume to attempt to picture zoölogy as a unified science. There are excellent books that supply a knowledge of the animal kingdom—this one aims to add some knowledge of the science itself. It is, therefore, intended to be a book of collateral reading for courses in practical zoölogy, and, while written with this primarily in mind, it is, at the same time, adapted to the needs of the general reader who wishes to become familiar with the progress of zoölogy.

In the preparation of the material I have been indebted for helpful suggestions to my colleagues, Professor Sidney I. Kornhauser and Dr. Olof Larsell. I am also indebted to the Macmillan Company for permission to use verbatim a considerable portion of my article "Zoölogy" published by that firm in *A Cyclopædia of Education*, 1913.

William A. Locy.

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# THE
# MAIN CURRENTS OF ZOÖLOGY

## CHAPTER I

## ZOÖLOGY AS A SUBJECT OF GENERAL EDUCATION. OUTLINE OF THE PROGRAM

THERE are no problems of greater human interest than those of biology, and when we recognize that zoölogy is the central subject of biology it immediately emerges for consideration as a subject of general education. The richness of zoölogy as a science and its many-sided appeal is just beginning to dawn on those who arrange courses of study. Owing, however, to the way in which it is commonly pursued attention is so exclusively confined to observations of animals and the means of identifying them that the student is not made aware of its other aspects and, as a consequence, a narrow conception of its scope has prevailed.

Although, in treatises on the subject, it has been well expounded from the standpoint of the structure, the development and the life histories of animals, the

plain story of how zoölogy arose and of how it became closely related to human affairs has not been told.

There has been too little attempt to picture zoölogy as a unified science. Even among those who have studied zoölogy, knowledge is little disseminated regarding its scope, the results, both material and intellectual, of its progress and the kind of work that is being carried on at the present time. Scarcely known are the names of its foremost men, their relative rank and the reasons for their eminence.

These matters are not only important, they are essential to an understanding of what zoölogy is and what it stands for.

To say that zoölogy is the science that acquaints us with animals and the phenomena of animal life—which is a fair definition—gives no clue to the part it has played in intellectual development and in the interpretation of the organic world. Its advances brought a new class of ideas into man's intellectual horizon, which resulted in dispelling error, in spreading enlightenment and produced some changes of opinion of epoch-making importance.

There resulted from zoölogical discovery the sweeping conclusion that the human body belongs to the animal series and, consequently, that observa-

tions regarding animals and their relation to nature apply also to the human body and to the question of man's place in nature.

This truth was a long time gaining credence since it was in conflict with ideas that had prevailed for centuries and its final acceptance brought a revolution of opinion.

The recognition of this oneness of nature, especially as applied to the animal world, is one of the most dramatic results of scientific advancement. It is continually illustrated in a great variety of relations:—the similarity of stages of embryonic development of all animals, the gradual building of body and of mind, the ultimate bearing of these questions on human origin and destiny. It led to the analysis of the phenomena of life, reduced to their simplest expression in the lower organisms, in order to throw light on the vital activities of higher animals. It also led to including man in the scheme of organic evolution and opened many other new questions.

Naturally, a subject of such wide scope and of such varied aspects presents particular difficulties of treatment and it is further complicated by the traditional method of the study of animal forms to the exclusion of other major topics. The question of

what must be included in the exposition of zoölogy and what may be omitted becomes a perplexing one.

Accordingly, at the outset, it is of primary importance to get an idea of what is embraced within the zoölogical territory and to determine the method of analysis so as to give, if possible, a unified view of this many-sided science. Undoubtedly, the bewildering number of details makes it difficult to deal with them clearly and coherently. The attempt to unite them into an orderly whole runs the risk of becoming merely discursive. The matter, however, is greatly simplified by the circumstance that in the progress of zoölogy, notwithstanding the continual multiplication of details, there has been continuity of development of zoölogical thought. If we can follow the path, the large number of details serves to enrich the subject with numerous illustrations without confusing it.

The first step of our program should be to determine the main currents of zoölogical progress and, thereafter, to become acquainted with the circumstances under which they were started and their ultimate outcome.

The direct study of animal types will not suffice. Laboratory exercises and observation of animals in

the field are necessary, but experience has repeatedly shown that this in itself is not sufficient. Such studies should be supplemented by the story of the rise of zoölogy and a systematic account of its discoveries of first magnitude.

As indicated above, these aspects of zoölogy are so commonly neglected that students emerge from the study of the subject, possessing only a certain set of facts about animals—with detached fragments of zoölogical knowledge—and no conception of zoölogy as a department of human learning. The fact is that the outlook on zoölogy has been too narrow, and we should become more aware of the results of zoölogical study and not limit our vision merely to facts about animals—in a word, more cognizant of the ideas and theories of zoölogy.

Considerations of this nature serve to indicate that a knowledge of the main currents of zoölogy should be acquired in connection with the facts of observation learned in the laboratory and in the field. To orient ourselves toward the subject we should at least know the great movements, the foremost men, in a broad way the influence of their researches, and the present tendencies of the science.

It is the purpose of the following chapters to supply

such an account—untechnical and not in too great detail. There are excellent text-books, in which the animal kingdom is systematically considered, but there is need of a source of collateral reading to supplement these text-books and to run parallel with laboratory work and field observations.

**Position of Zoölogy in Biology.**—To fix the place of zoölogy we need only to remember that one of the most striking developments of the past half-century has been the great extension of knowledge of organic nature and the new interpretations that have resulted. Since zoölogy is the central subject of this biological advance, it has come about that this science embodies our interpretations of organic nature. There comes within its province consideration of all the phenomena of animal life and of what has grown out of their study:—Evolution, genetics, heredity, biogenesis, Mendelism, transmission of disease through animal agencies, structure, development, habits, animal intelligence and behavior. These and kindred matters find in zoölogy their illustrations and their systematic treatment.

Inasmuch as most animals possess a nervous system, which is lacking in plants, zoölogy gives a fuller representation of vital phenomena than its sister

science botany, and it has been more intimately concerned than any other subject in expanding our ideas of the human body in its relation to nature.

Owing to the character of the questions involved and to its broad scope, the foremost claim of zoölogy to attention is as a subject of general education. Education to-day without some knowledge of the phenomena of nature is inadequate. Some training in the scientific method of observation, such as is supplied by zoölogy, is an indispensable part of the mental equipment of the liberally educated.

The results of zoölogical investigation have practical bearing in sanitary science, in the conservation of useful animals, for the agriculturist, the breeder and the economic zoölogist. While supplying training and important knowledge of the animal life referred to, the subject affords opportunity for diversion in the study of birds, marine forms and insects.

Besides its position in general education zoölogy is basal to the study of medicine. Not only have zoölogical discoveries enriched medicine, but, furthermore, they have supplied the foundations upon which experimental medicine has been built. Zoölogy is one of the important pre-clinical subjects, and all

students preparing for the profession of medicine should engage in the study of zoölogy, not merely as supplying training in the kind of observation that is needed for diagnosis, but as affording a broader outlook on the structure, the development and the physiology of the human body. It affords to-day the best introduction to general physiology.

In addition to its inseparable connections with botany, zoölogy is closely related to two other sciences—physics and chemistry. Zoölogy and botany are essentially the sciences of organic nature, while physics is the science of inorganic nature. In the study of nature the biological and physical sciences are fundamental and reciprocal to one another.

Chemistry is somewhat more closely allied to biological phenomena since these phenomena are physico-chemical in their nature and the great development of physiological chemistry has brought it into very close relation with biology. A certain knowledge of chemistry is necessary to the understanding of any physiological problem. Chemistry, physics and biology form the tripod of sciences essential to the student of medicine.

Zoölogy has been made by the confluence of many

scientific currents and it cannot be properly treated in isolation. Especially that which is broadly biological is a part of zoölogy as well as of botany.

In attempting to find the main currents of zoölogy let us begin with the chief biological advances of the nineteenth century.

## CHAPTER II

## THE OUTSTANDING BIOLOGICAL ADVANCES OF THE NINETEENTH CENTURY

The events of the nineteenth century have a relatively near-by interest. Accordingly, it will be first in order to inquire what are the biological advances of widest influence of the past century?

Many advanced students of zoölogy would be puzzled if called on to separate the truly outstanding events of zoölogical progress from those of subordinate importance. There were so many biological advances in "The Wonderful Century" that the task of selecting those to stand in the front rank requires much discrimination. The basis for selection is not the brilliancy of individual discoveries, nor unprecedented progress in special fields, but the consequences that followed unique discoveries and the extent to which they influenced the whole field of biology.

Instances of notable advances will at once emerge for consideration such as: the establishment of embryology on modern lines by Von Baer (1828), the discovery of the nucleus of plant cells by Robert

Brown (1831), the work of Johannes Müller in animal physiology, the development of vegetable morphology by Hofmeister and of vegetable physiology by Sachs and Pfeffer. These are biological, but important as they were, they did not influence the whole field of biological science as did those events now referred to as the outstanding biological advances of the century.

To avoid repeated explanation, it is to be understood that the term "biological" is generic and implies botanical as well as zoölogical advances, but it is used here in the restricted sense of "biological" from the animal side.

Considered from the standpoint of wide influence, there are five biological advances of the nineteenth century to which all others are subordinate. These are: the discovery of protoplasm; the formulation of the cell-theory; the establishment of the theory of organic evolution; the demonstration of the germ-theory of disease in connection with the rise of bacteriology, and, fifth, the experimental study of heredity. There was a parallel development of these subjects but, for clearness, separate consideration is necessary.

**The Discovery of Protoplasm.**—The scientific

discovery of protoplasm came in 1835, though its significance was not recognized until twenty-five years later. This living substance, common to plants and animals, had been casually observed, at intervals, from 1755 onwards. Under the microscope its movement had been detected in the proteus animalcule, by Roesel von Rosenhoff in 1755. Thereafter, in plants, by Myen, in 1827, and by other observers. But all these observations were substantially pointing out the existence of movements of a semi-transparent jelly-like substance in animals and plants.

An important forward step came in 1835 when Félix Dujardin (1801–1860), a French naturalist, published discriminating observations on this living substance in simple animals such as various protozoa and worms. Not content with merely observing its movements, he experimented with it, and by applying tests as to its solubility and behavior towards different reagents, he distinguished between it and gum, gelatine, mucus and white of egg, with which it has superficial resemblances. Finally, in 1835, he described it as a "living jelly endowed with all the properties of life." His predecessors had not observed it in this way; consequently, it is proper to designate Dujardin as the scientific discoverer of

protoplasm. He called it sarcode, from the Greek, meaning flesh-like.

Although Dujardin pointed out that sarcode was a different substance from any other known to science, and that it was endowed with all the properties of life, he was far from recognizing the distinctive rôle it plays in nature. The conclusion prevailed that it was confined to the lower animals, and this long delayed the recognition that it is the living substance of all organisms—including, of course, the human body. To reach this point took twenty-five years of investigation by various men.

The name sarcode was not retained and the circumstances under which the original name was changed to protoplasm may be briefly stated. Eleven years after Dujardin's discovery, the German botanist, Hugo von Mohl (in 1846), described the same slimy substance in plants under the name protoplasma. In the interval, it had been described, in 1840, under the designation protoplasm, in mammalian embryos, by the Bohemian anatomist Purkinjé.

In 1846, after von Mohl's publication, the scientific world was in the position of knowing "sarcode" of lower animals, and "protoplasm" in certain animal embryos as well as in plants.

There now began to rise the suggestion that sarcode and protoplasm were different names for one and the same substance and, in 1850, Ferdinand Cohn definitely maintained that protoplasm and sarcode were identical substances. Later in life Cohn became eminent for investigations in bacteriology but, at this time he was a young man of twenty-two years and his contribution was considered theoretical and insufficiently supported by observation and experiment.

With Max Schultze (1825–1874), came the summation of the accumulated knowledge regarding protoplasm and the final step in bringing it into full recognition in the scientific world. After a long series of observations and experiments he announced, in 1861, that living substance, be it called sarcode or protoplasm, is essentially alike in animals and plants. He reached this conclusion largely upon physiological resemblances, pointing out, especially, that the contractility exhibited by all protoplasm is essentially similar to the contraction of muscles.

One thing that had stood in the way of an earlier recognition of the true nature of protoplasm was, that for some years, it was supposed to be confined to lower animals and it was necessary that observa-

tion should establish that it is universal in all organisms before the general conclusion could be reached.

Let us now estimate the consequences of the discovery of protoplasm. Here for analysis we have disclosed the living substance of all animals and plants. In this physical substratum all vital activities exhibit their manifestations. Now for the first time was recognized the basis of physiological activities. If the naturalist is ever to bring vital activities under close analysis, he must do so by becoming acquainted with the properties and the behavior of protoplasm. Even in its simplest form it exhibits the germ of all properties that appear better developed in higher organisms.

The recognition of the nature of protoplasm, together with the adoption of the cell-theory, led to the foundation of modern biology, and the progress of biology, since 1861, has been largely a matter of becoming better acquainted with protoplasm. By means of these discoveries vital phenomena were seen in a new light and progress was started.

It is to be remembered throughout this book that a great scientific discovery is never the product of one man, nor of two men. Although in bringing forward

the protoplasm idea, Dujardin (Fig. 1) and Max Schultze (Fig. 2) occupy the foremost position, a great many other investigators, as the botanists De Bary, Nägeli, Strassburger and others contributed to this end.

**The Cell-Theory.**—The cell-theory had a parallel development with the protoplasm idea and, ultimately, they fused as one. The cell-theory was announced in 1838–1839, a few years after Dujardin's discovery of protoplasm.

The microscopic examination of a thin section of a plant stem, a similar section of hardened liver, scrapings from the inside of the human cheek, the skin of a frog, the skin, or epidermis, of a plant, all reveal similar units of organic architecture. Further studies show that brain tissue, bone and cartilage, in fact, all organic tissues are constructed by the union of microscopic elements nicely fitted in together. This is the basis of the cell-theory, but it is a long step from mere observation of these elements to the generalization that all animals and plants are composed of a union of similar cells. The latter conception in its full sweep unites all living creations on the broad plane of similarity of structure and, as we shall soon see, of similarity of origin—since all organisms,

FIG. 1.—FÉLIX DUJARDIN (1801–1860)

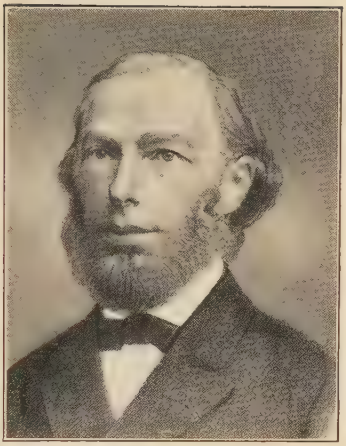

FIG. 2.—MAX SCHULTZE (1825–1874)

FIG. 3.—THEODOR SCHWANN (1810–1882)

FIG. 4.—THEODOR BOVERI (1866–1916)

no matter how complex, begin their existence in the condition of a single cell.

This "master-stroke of generalization" had a wonderful unifying effect in bringing all animals and plants under one view as to origin and structure.

The names of two men, Schleiden and Schwann, are associated with the launching of this theory. Schleiden was a botanist, and Schwann, an anatomist—a happy combination in biological investigation. They are commonly spoken of as the co-founders of the cell-theory. This statement, however, requires qualification, for the part played by the two men was very unequal. Schwann, so to speak, was the star and Schleiden played a subordinate part.

Schleiden's work was auxiliary. He had observed cell formation and cell structure of plants and published a small paper on this subject in 1838. In a friendly conference, he assisted Schwann, whose researches were already the more extensive, by suggesting that the nucleus (cytoblast) of the animal tissues, examined by Schwann, was the same as the nucleus of plants and this, apparently, flashed into the mind of Schwann, the identity of organization of animals and plants.

Schwann (Fig. 3) in an extensive paper (215 octavo pages, with four plates), published in 1839 first employed the term "cell-theory" and explained its meaning. This treatise, which is a biological classic, was his famous *Microscopical Researches regarding the Accordance in Structure and Growth of Animals and Plants* (*Mikroscopische Untersuchungen über die Uebereinstimmung in der structur und dem Wachsthum der Thiere und Pflanzen*).

Schwann's writing in the *Microscopical Researches* is clear and philosophical, and is divided into three sections, in the first two of which he confines himself strictly to descriptions of observations, and in the third part of which he enters upon a philosophical discussion of the significance of the observations. He comes to the conclusion that: "The elementary parts of all tissues are formed of cells in an analogous, though very diversified manner, so that it may be asserted that there is one universal principle of development of the elementary parts of organisms, however different, and that this principle is the formation of cells."

It was in this treatise also that he introduced the term cell-theory as follows: "The development of the proposition that there exists one principle for the

formation of all organic products, and that this principle is the formation of cells, as well as the conclusions which may be drawn from this proposition, may be comprised under the term *cell-theory*, using it in its more extended signification, while, in a more limited sense, by the theory of cells we understand whatever may be inferred from this proposition with respect to the powers from which these phenomena result."

Schleiden had not used the term cell-theory, nor developed the ideas at the basis of it, accordingly it is more proper to give the credit to Schwann for this great generalization and to speak of it as the cell-theory of Schwann rather than the cell-theory of Schleiden and Schwann.

There were serious defects in the theory as it existed in the minds of the early observers. Both Schleiden and Schwann attached importance to the cell-wall and had a wrong idea of the nucleus (called cytoplast by Schleiden) and of the formation of cells. But, as researches progressed, the theory was greatly expanded and improved.

One of the most helpful steps was the full recognition of the origin of cells in multicellular organisms. The many-celled animals and plants begin their

existence in the condition of a single cell, and from this primary condition, the many cells arise by successive divisions of the original one. These many cells become separated into different groups which exhibit different properties, and, by the combination of cells having similar properties, the tissues arise. When, finally, about 1865, all eggs, as well as their fertilizing agents, or sperms, were recognized as cells, we had the logical explanation of the origin of cells, and, also, an insight into the nature of tissues.

At the time of Schleiden and Schwann a cell was thought of as a box-like compartment or a little space surrounded by walls but, presently, this conception was materially changed. The cell-wall was seen to be formed by the living protoplasm within, and attention became directed to that substance as the essential part of the cell. Many animal cells were observed without cell-walls and the conclusion was soon reached that the cell-wall is unimportant and may be lacking. Accordingly, about 1860, Max Schultze defined the essential qualities of a cell as "A mass of protoplasm containing a nucleus." Up to this time the cell-theory was chiefly a morphological doctrine, but now combined with the protoplasm idea, which was essentially physiological, it assumed a wider significance.

From this point ideas began to broaden and other new relations were discovered. The minute structure of the cell was investigated, the centrosome and the chromosomes were discovered, the behavior of these parts and of the nucleus were observed. The phenomena of fertilization of the egg, the mechanism of heredity and the seat of hereditary qualities were studied as problems pertaining to cell life.

So many sweeping conclusions resulted that a new branch of biology having to do with the phenomena of cellular life was organized. This division was called cytology and the late Theodor Boveri (1866–1916) (Fig. 4), was perhaps its leading representative on the zoölogical side.

In its modern statement the cell-theory has come to embrace four aspects which successively have been developed. These are: the conceptions of the cell as a unit of structure; the cell as a unit of physiology; the cell in development and in heredity. The title of Wilson's, now classic, book on *The Cell in Development and Inheritance* carries this idea. (For comments on the cell in inheritance see p. 43.)

From these considerations it becomes evident that the cell-theory and the protoplasm idea are broad generalizations that influenced the entire

field of biology and classes them as outstanding advances.

**The Doctrine of Organic Evolution.**—The doctrine of organic evolution is so comprehensive in its range that it has entered into the whole frame-work of human thinking and its acceptance has so profoundly changed conceptions of man and nature that it has produced a great mental revolution. There is a natural cleavage between thought before 1859 and thought after that date regarding the biological interpretation of the universe. The doctrine of organic evolution has done more to enrich zoölogy than any other advance. In its full sweep it is one of the greatest acquisitions of human knowledge. Although utilized in different departments of learning it is a biological doctrine and receives its fullest illustration in zoölogy. It is the recognition that the higher animals have been derived by modification from the simpler ones and it cleared up many of their heretofore perplexing relations. It is the discovery of the lineage of animals and plants.

Although it is commonly believed that Charles Darwin (Fig. 5) was the founder of this doctrine it was clearly expressed more than fifty years before the publication, in 1859, of Darwin's *Origin of*

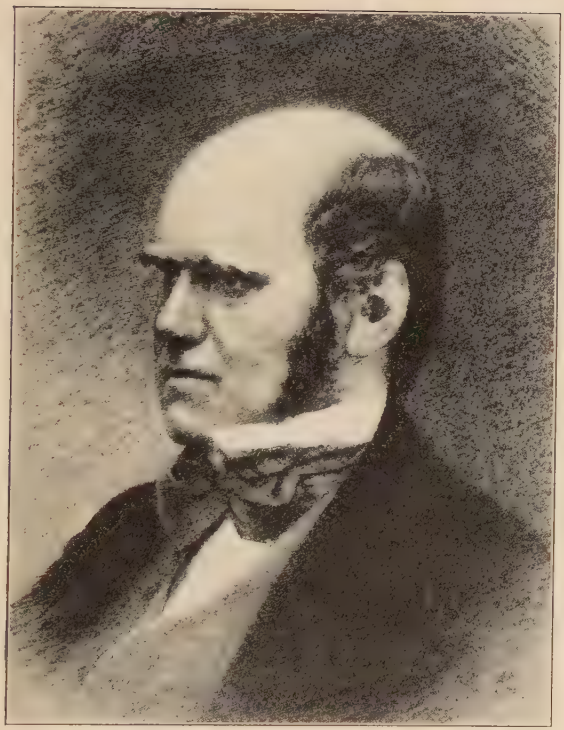

FIG. 5.—CHARLES DARWIN (1809–1882)
A few years prior to the publication of *The Origin of Species*

*Species.* The French zoölogist, Lamarck (1744–1829) was the first to announce, in 1801, a comprehensive theory of evolution that has lasted to the present, while Darwin's especial contribution was the designation of natural selection as the chief agency in bringing about the evolution of animals and plants. Besides these two, the theories of Weismann and De Vries have attracted the most attention.

This doctrine is so important and so intricate that in a later chapter it will be returned to for fuller exposition of the different theories.

## CHAPTER III

## THE OUTSTANDING BIOLOGICAL ADVANCES—CONTINUED

After such high praise of the theory of organic evolution, what can remain to be said of the advance resulting from the biological work of Pasteur, Koch and Lister?

The theory of Organic Evolution is philosophical and wide-reaching, but the results of the study of micro-organisms, with which Pasteur and others were concerned, had more immediate practical applications.

The science of bacteriology embraces several general questions such as, the germ-theory of disease, the nature of fermentation, of inflammations, the spontaneous origin of life, immunity, etc. In this group of topics certain animal and plant organisms are so intertwined as to their aspects and effects that it is artificial to attempt to draw a sharp line separating the bacteria from all other organisms. When strictly limited, bacteriology should be confined to bacteria, which are minute plants, but, as the experimental study of these micro-organisms advanced, it

was inevitable that some minute animal organisms also should become involved. This overlapping of closely related fields of investigation is so common that it may be accepted as characteristic.

For our present purpose we shall not take up specifically the various topics, mentioned above, but, under the general caption Bacteriology, treat in a general way of the movement and its results.

**Rise of Bacteriology.**—The rise of bacteriology with its germ-theory of disease had far-reaching consequences for the benefit of mankind; there is, in fact, no biological advance that has had more important bearings on the welfare of the human race.

The micro-organisms are so minute that one would scarcely expect them to play an important part in human affairs. The world of exceedingly minute life was first exposed by the Dutch microscopist, Leeuwenhoek, who, in 1675, discovered the protozoa and, in 1683, the bacteria. The protozoa are microscopic animals while the bacteria are microscopic plants. The more general term micro-organisms is convenient as it includes them both—and, of course, other minute plants that are not bacteria. It was

nearly two centuries after Leeuwenhoek's discovery before these organisms began seriously to be considered as of practical interest.

We cannot assign a definite date as the time of the beginning of bacteriology. It took form gradually. The researches of Ferdinand Cohn on the bacteria, published at various times between 1853 and 1872, form an important preliminary preparation. This is especially true of his classification of the bacteria which in its larger features is essentially the one used to-day. If, however, any single man is to be considered as the founder of bacteriology that man is Louis Pasteur, while for Robert Koch we reserve the distinction of having lifted it into the position of an independent science.

For convenience we may arbitrarily adopt the date 1877, as being the time when bacteriology sprang into general recognition. In that year both Pasteur and Koch demonstrated that splenic fever, a specific disease of sheep and cattle, is owing to the growth within the body of a specific micro-organism called the anthrax bacillus (*Bacillus anthracis*). Previously, Pasteur had shown the nature of fermentations (1857) and discovered the connection between microscopic particles and silk-worm diseases

(1865), while Robert Koch in 1876 had made a study of the growth of the anthrax bacillus.

In the early days, the men chiefly concerned in bringing bacteriology into practical use were Pasteur, Koch and Lister—all great benefactors to the race.

**Pasteur.**—The brilliant work of Pasteur (1822–1895), Fig. 6, belongs to all biology. Starting his scientific career as a chemist, he was soon drawn into the investigation of biological problems, and, through his later work, came to be recognized as one of the foremost men of biological history. He left a heritage of priceless value which will make his fame as enduring as that of Aristotle. His supreme service was in applying the results of biological investigation to the benefit of mankind.

In laying the foundations of micro-parasitology (about 1877), Pasteur opened a subject that overlaps the different conventional division of biology, and his foundations have been built upon by botanists, zoölogists and physicians. His investigations gave an immense impulse to the study of pathogenic organisms; and while his researches supplied the foundations of scientific medicine, at the same time they opened investigations in the life-history of micro-organisms that have been extensively devel-

oped by zoölogists—as in the notable work of Fritz Schaudinn and others.

One of Pasteur's early triumphs was the demonstration of the nature of fermentation (1857). This process, which is so important in physiology, was declared to be due merely to chemical action, but Pasteur showed that it depends on the growth of living micro-organisms, and he won his case against the great opposition of the chemist Liebig.

Against his inclinations Pasteur was forced into the controversy (with Pouchet), concerning the spontaneous generation of life, and, in 1862, made his decisive and epoch-making demonstrations—that life is formed in nutrient fluids only when living germs are allowed to enter from the outside. All this directed attention to the constitution of the floating matter of the air. The impalpable dust that is always present and that shows in the path of a sunbeam through a darkened room is of complex composition—besides particles of non-living matter there are living organisms of different kinds in a dried condition. Some of these are harmless and others are disease producing. When floating germs are introduced into canned fruits and meats, they grow and cause them to spoil. Other kinds entering wounds produce

FIG. 6.—LOUIS PASTEUR (1822–1895)

suppuration and other diseased conditions. Still other kinds may produce diseases when breathed into the lungs, or, introduced into the body through milk, water and various kinds of food. These discoveries are of the utmost importance.

Those micro-organisms that cause canned fruits and tinned meats to decompose are killed by heating and when, thereafter, the cans are securely sealed the contents are preserved in a wholesome condition. Even more important than this was the recognition (1865–1867) of the Edinburgh surgeon, Lister (Fig. 7) that to keep the floating germs from surgical wounds would prevent gangrene and pus formation. Against great ridicule and opposition, Lister made his experiments, using carbolic acid dressings and great cleanliness and, about 1867, established the method of antiseptic surgery. This followed as a consequence of Pasteur's studies but the credit for this application belongs to Lister (1827–1912). At first it made slow progress against the contemptuous criticisms of medical men, but the successes that accompanied its practice were so overwhelming that this great advance in surgery became established.

Pasteur was soon led to experiment with diseases of

animals such as splenic fever of sheep, cholera of swine and fowls, and, through his efforts, and those of contemporary workers, it was repeatedly demonstrated that a particular micro-organism is the cause of a particular disease. That most disease organisms produce poisons or toxins within the system was demonstrated and, thereupon, Pasteur began successful attempts to produce serums, vaccines and antitoxins to counteract the poisons produced by the growth of disease germs within the body.

Progressing by a series of ascending steps he finally (about 1880) turned his attention from animal diseases to infectious diseases of the human body, and there he applied the same principle in the production of antitoxin injections.

Having proved the efficacy of vaccines in animal diseases Pasteur devoted himself to the means of combating diseases of the human body. He chose a comparatively obscure human disease, hydrophobia, but as results showed made a wise selection, and in working it out to a successful conclusion he established the principles on which future advances were to be made. In 1880 he was already engaged in the study of hydrophobia and in 1885 he made his first treatment of a human being—a young boy from

Alsace. This treatment was successful as his inoculation of animals had been.

The time had now come for the establishment of the Pasteur Institute which was opened in Paris in 1888. This, the first institute of its kind, became the parent of numerous similar institutions that have been established in many cities throughout the civilized world.

As Frankland says in his *Life of Pasteur:*—"The extraordinary enthusiasm which accompanied the foundation of this great Institution has certainly not been equaled in our time." This took popular form. "Considerable sums of money were subscribed in foreign countries whilst contributions poured in from every part of France. Even the inhabitants of obscure little towns and villages organized fêtes and clubbed together to send their small gifts." With the lively appreciation of the French for science and its unselfish achievements the opening of the Institute was regarded as of national importance. On November 14, 1888, it was opened with impressive ceremonies presided over by the President of the French Republic. Thus, after a long period of struggle and strong opposition such as often falls to the lot of innovators, Pasteur came to honor and recognition.

The Pasteur Institute must not be thought of as founded chiefly for the treatment of hydrophobia—this is merely incidental. It is organized for the complete investigation of bacteria and all manner of serum injections and vaccines for the control of diseases. In the Paris Institute, Émile Roux, the present Director, perfected and proved the efficacy of the antitoxin of diphtheria (independently discovered by Behring in 1892). From it has emanated, directly or indirectly, such important procedure as vaccination against typhoid fever, the serum treatment of bubonic plague, etc. Without the superb work of Pasteur these advances could not have taken place.

**Koch.**—Robert Koch (Fig. 8) was born in 1843, and for several years before his death in 1910, he was the Director of the Institute for Infectious Diseases in Berlin. His investigations were mainly those of a medical man and were crowned with remarkable success. In 1881, he discovered the bacillus of tuberculosis, in 1883, the specific germ of Asiatic cholera, and since that time his name has been connected with many notable discoveries that are of continuous practical application in the science of medicine. He was so ingenious, so highly trained and

so incisive in analysis, that from time to time he was called on by different countries to assist in the investigation of the causes and means of control of infectious diseases—such as Asiatic cholera, the bubonic plague and the sleeping sickness of Africa.

Koch was intimately concerned in establishing bacteriology as an independent science. In 1882, he introduced into bacteriological study the ingenious method of employing solid culture media. Bacteria are so minute that it was a perplexing problem to separate the several forms that are commonly mixed and to secure a pure culture of one kind. This was made possible by placing a liquid culture of the mixed bacteria in melted gelatine—and other media rendered liquid by heat. This mixture was stirred with a glass rod and by this means the bacteria were separated and distributed. The melted gelatine was now allowed to flow over a sterilized glass plate, making a thin film which hardened on cooling. In this manner the separated bacteria were held in place and as they grew in clusters, there were spots of pure or nearly pure culture. These spots were observed under the microscope, were picked off and planted again in liquid gelatine and the process repeated until pure cultures were secured.

These methods so obscure, and, at first, so difficult to ferret out are now commonly demonstrated in schools and training institutions. Many simple experiments are now tried which give evidence of the presence of these very minute germs in the air. By exposing plates of sterilized gelatine in shallow dishes with glass covers to keep out germs, in a room before and after sweeping, in crowded school rooms and in open country air, by allowing tap water to trickle across a sterilized gelatine film, by allowing a fly to walk upon it, etc. By these means the sterilized plates become infected, they are immediately covered and set away in a warm place. The growth of bacteria on the gelatine produces easily seen patches and give evidence of the existence of these germs which, individually, can be detected only by high magnification. It is obvious that the rise of bacteriology with its special problems exerted wide influence on all biological science and this justifies classifying it with the outstanding advances of the century.

**The Experimental Study of Heredity.**—The investigation of heredity is of surpassing interest. There are so many theoretical and practical questions involved. Perennial is the wish to know the way in

which hereditary qualities are passed from generation to generation and the conditions under which they are transmitted and by which they are qualified. This has led to much speculation and the formulation of various temporary theories of heredity that have given way to better ones. It is a long and involved story to trace the transformations of these theories, but, it may be said in a word, that, in the last decade of the nineteenth century, they were replaced by the theory of germinal continuity—one of the most fruitful ideas of nineteenth century zoölogy. This idea will be returned to under the evolution theory of Weismann.

The theories referred to were chiefly the result of speculative thinking, and more promising avenues were opened through the application of experiment.

The application of experimental and of statistical methods to the study of heredity was brought about chiefly by two men—Francis Galton, the Englishman, and Gregor Mendel, an Austrian monk.

Although Mendel conducted his experimental observations of heredity and published his results (1866–1867) before Galton had fairly begun, we shall see that Galton's results got into notice before those of Mendel and began to influence progress.

Accordingly, since his influence preceded Mendel's, Galton is commonly recognized as the founder of the scientific study of heredity. Observations of "Mendelian inheritance" began to be active only after the opening of the twentieth century.

**Galton.**—Francis Galton (1822–1911) Fig. 9, by directing attention to the inheritance of individual characters made the subject of heredity manageable. Previously, hereditary traits had been considered in their entirety, and the resemblances and differences of parents and their offspring had been averaged. This method was too diffuse, since no one could distinguish sharply among the multiplicity of characters; greater definiteness was introduced when Galton began to study hereditary characters separately.

Galton was the grandson of Doctor Erasmus Darwin and the half cousin of Charles. After publishing books on his travels in Africa, he began the experimental study of heredity, and in 1871, he read before the Royal Society of London a paper on the theory of inheritance. The observations upon which he based his conclusions were made by the transfusion of blood in rabbits and their after-breeding. Later he observed the method of inheritance of spots

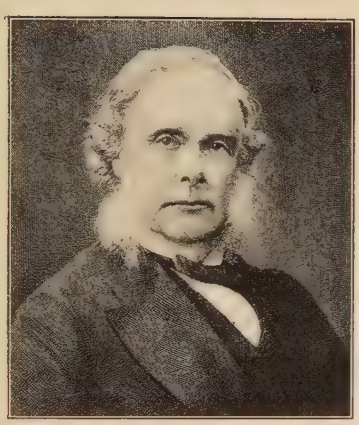

Fig. 7.—Sir Joseph Lister (1827–1912)

Fig. 8.—Robert Koch (1843–1910)

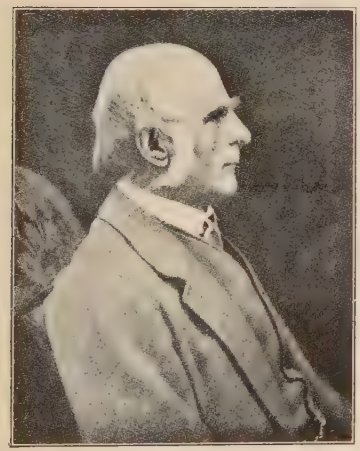

Fig. 9.—Sir Francis Galton
(1822–1911)

Fig. 10.—Gregor Mendel
(1822–1884)

on the coat of certain hounds, investigated by statistical methods the inheritance of stature and of genius in human families, etc. He was led by his observations to formulate a law of ancestral inheritance which received its clearest expression in his book, *Natural Inheritance*, published in 1889.

He was so deeply interested in Eugenics—the investigation of the conditions that improve, or impair, the races of animals—that he is to be remembered as the founder of that branch of biological knowledge.

**Mendel.**—The earliest experimental investigations of heredity were conducted with plants, and the first epoch-making results were those of Gregor Mendel (1822–1884) (Fig. 10), a monk and later abbot, of an Augustinian monastery at Brünn, Austria. In the garden of the monastery, for eight years before publishing his results, he made experiments on the inheritance of individual (or unit) characters in twenty-two varieties of garden peas. Selecting certain constant and obvious characters, as color and form of seed, length of stem, etc., he proceeded to cross these pure races, thus producing hybrids, and, thereafter, to observe the results of self-fertilization among the hybrids.

The hybrids were produced by removing the unripe stamens of certain flowers and later fertilizing them by ripe pollen from another pure breed having a contrasting character. The results showed that only one of a pair of unit characters appeared in the hybrids of the next generation, while the other contrasting character lay dormant. Thus, in crossing a yellow-seeded with a green-seeded pea, the hybrid generation showed only yellow seeds. The character thus impressing itself on the entire progeny was called *dominant*, while the other that was held in abeyance was designated recessive.

That the recessive color was not blotted out was clearly demonstrated by allowing the hybrid generation to develop by self-fertilization. Under these circumstances a most interesting result was attained. The filial generation, derived by self-fertilization among the hybrids, produced plants with yellow and green seeds, but in the ratio of three yellow to one green. All the green-seeded individuals and one-third of the yellow proved to breed true, while the remaining two-thirds of the yellow-seeded plants, when self-fertilized, produced yellow and green seeds in the ratio of three to one.

Subsequent breedings gave an unending series of

results similar to those obtained with the first filial generation.

This great principle of alternative inheritance was exhibited throughout the extensive experiments of Mendel, and it is now recognized as one of the great biological discoveries of the nineteenth century. Mr. R. C. Punnett gives (1905) a remarkably clear and terse statement of the facts as follows: "Whenever there occurs a pair of differentiating characters, of which one is dominant to the other, three possibilities exist: there are recessives which always breed true to the recessive character; there are dominants which breed true to the dominant character, and are therefore pure; and, thirdly, there are dominants which may be called impure, and which on self-fertilization (or in-breeding where the sexes are separate) give both dominant and recessive forms in the fixed proportion of three of the former to one of the latter."

The results of Mendel's experiments are the consequence of the fact that the germ-cells retain their purity with respect to unit characters. That is, in the combination of germ-cells by cross-breeding, the hereditary qualities do not lose their individuality—they are mixed but not blended. When the germinal

elements are formed in these hybrid plants two classes of germ-cells will arise in equal number, one class carrying the dominant and the other the recessive quality. Chance combinations of these germ-cells will yield on the average, one union of dominant with dominant, one union of recessive with recessive, and two combinations in which dominant and recessive are united. In the latter instance the dominant will be the visible character, the recessive, though present, being invisible. This segregation of the gametes into two sets of "pure" gametes was recognized by Mendel in an attempted theoretical explanation of his observed facts, and, in view of the state of knowledge at the time, showed remarkable analytical ability.

Mendel's papers were published in 1866 and 1867 in the proceedings of the Natural History Society of Brünn, but their importance was overlooked for nearly thirty-five years. The periodical in which they appeared was not widely known, and moreover, the minds of naturalists at that time were largely occupied with the questions of organic evolution raised through the publications of Darwin. In the year 1900, however, the great principle of heredity worked out by Mendel was independently redis-

covered by the botanists De Vries, Torrens, and Tschermak. By searching the literature for anticipations of their results, the unrecognized papers of Mendel were brought to light and made generally known to the scientific world.

Since 1900, extensive experiments by Bateson and many others have served to confirm and extend Mendel's discovery. In the United States the experiments of Davenport and of Castle on inheritance in poultry, the inheritance of fur in guinea-pigs, erectness of ears of rabbits, etc., the far-reaching experiments of Morgan with the fruit-fly, as well as the experimental work of others, have extended our knowledge of Mendelian inheritance. The combined work on inheritance in animals and plants of all observers has so thoroughly supported Mendel's conclusions, that the principle of alternative inheritance is commonly spoken of as Mendel's law.[1]

Other investigations have led to the recognition of the physical basis of heredity and to the idea of germinal continuity. Within the nucleus of cells of plants and animals there are certain very minute bodies, the chromosomes (discovered 1883), which

[1] The seven paragraphs above are quoted from the writer's *Biology and Its Makers.*

stain deeply with micro-chemical dyes. These are believed to be the bearers of heredity.

Since the germinal cells of plants and animals must be fertilized before they develop, we find in the chromosomes the source of maternal and of paternal qualities—because fertilization is essentially a union of the chromosomes of egg and sperm. Eggs in getting mature lose one-half their chromosomes, sperms, or their fertilizing agents, also in course of formation have their chromosomes reduced by one-half. Now the egg is fertilized by the union of the sperm with it, and the fertilized egg is bi-parental. One-half the chromosomes of the fertilized egg come from the mother and one-half from the father. The maternal chromosomes (of the egg) and the paternal (of the sperm) are the bearers of the hereditary qualities of both parents. In considering the cell-theory it was pointed out that the problems of heredity are at bottom cellular problems and the statements just made will help to illustrate that point.

In closing this review we may re-affirm, that, on account of their wide influence on the entire field of biology, the five events designated all qualify as outstanding biological advances of the nineteenth century.

## CHAPTER IV

## ZOÖLOGY EMERGES

After analyzing its five outstanding advances and before proceeding to discuss other steps of biological progress we should make a digression to consider the circumstances under which science developed, and, in particular, those conditions that led to the emergence of zoölogy as a separate science.

As in human affairs present conditions can be understood only in the light of precedent conditions, so in zoölogy, a brief sketch of its rise is essential to an intelligent comprehension of the subject.

It is not necessary to attempt to picture the crude beginnings of observations of animated nature, and the dawning of simple ideas regarding animals and plants. The hunters, the poets, the artists of antiquity and the primitive nature-searchers accumulated facts of observation and invented many fables about animals. Fact and fable were intermingled and molded into a crude natural history of animals which existed long before the advent of Aristotle.

Knowledge of nature among the ancients reached its highest development in the Greek philosopher

and naturalist Aristotle (384–322 B. C.) (Fig. 11). He was a man of vast intellect engaged in a variety of intellectual occupations. In addition to writings on metaphysics, rhetoric, etc., he wrote and lectured on the natural history of animals (*Historia Animalium*) as an independent subject. It is noteworthy that at this early day, in his scheme of zoölogy, he subordinated the ideas of classification to his observations on structure (*De Partibus Animalium*) and development (*De Generatione Animalium*). These are the three books of Aristotle on zoölogy that have been handed down to us. He made extensive studies of life histories and recorded many facts that were rediscovered only in the nineteenth century.

The circumstance that made Aristotle eminent in science (outside his superb natural talents and his industry) was his method. He was the greatest investigator of antiquity! While we commonly think of him as standing at the beginning of science, he was, in fact, preceded by a large number of observers whose writings and verbal utterances are lost. Although living in the fourth century before Christ he speaks of "the ancients" in his writings and says that he took into account their observations in establishing his natural history, but he says, further, that

his effort to organize the subject is the first attempt and in that regard he had no forerunners.

The designation "the greatest investigator of antiquity" is significant since it implies that the notable development of science among the Greeks was owing chiefly to their method of inquiry—the direct observation of nature and the application of reason to the data thus gathered. Had investigation remained the method of ascertaining truth, the history of intellectual development would have been far different.

**The Arrest of Inquiry.**—With the overthrow of ancient civilization the conditions of mental life were so altered that there came about an arrest of inquiry that bred ignorance and led to the decline of science. All independent observation ceased. Men no longer interrogated nature by the method that had proved so fruitful. This condition of human development supplies an answer to the question continually raised—"Why was there no direct development of learning on the splendid Greek foundation?"

With the sweep of the barbarian hordes from the north over the civilized people of the south, monuments of civilization were destroyed, libraries were pillaged and burned, books became scarce and, subsequently, were housed chiefly in the monasteries.

General ignorance prevailed. The means of dissemination of knowledge did not exist, but the chief factor in the overthrow of learning was the arrest of inquiry into natural phenomena and the substitution therefor of a metaphysical method. The priesthood had access to the manuscript writings, and they, with the medical men of the period, became the educated classes. Under these conditions the direction of intellectual life was assumed by the theologians who were chiefly interested in contemplation of the spiritual and the supernatural and the medical men were submerged by the general change in the intellectual atmosphere.

A world-shunning spirit was engendered that was hostile to scientific inquiry and observations of nature came to be looked on as prompted by impious curiosity, and as an attempt to pry into the secrets of the Creator. Without the wholesome effect of observation and experiment, mystical explanations were invented for natural phenomena and ignorance and superstition prevailed. To question the mystical interpretations of nature was to invite theological persecution. No science could prosper under these conditions, and zoölogy languished in common with the other sciences.

A barren period of intellectual life followed. Although the intellectual life of the middle ages was active among theologians, philosophers and other educated classes it was so directed that for a period of a thousand years, under the dominance of theological authority, no really productive writings resulted. The leading medical men kept alive some spirit of investigation but it was confined to their own craft and was handed along by preceptor to pupil without becoming common property. Their occupation brought them into touch with natural phenomena. They knew the properties of herbs and their effects on the human body. They became acquainted to a limited degree, with anatomy and physiology. Finally, it was through the medical men that renewal of observation on organic nature was brought about.

**Renewal of Observation.**—Nearly nineteen centuries after Aristotle there occurred, as one of the features of the Renaissance, a revival of the scientific method bringing once more into human affairs the indispensable conditions even for the existence of science. As the decline of science had been largely due to the arrest of inquiry, and the substitution of authority for investigation as the method of ascertaining truth, so the renewal, so far as progress of

zoölogy was concerned, was a return to the observation of nature.

This new movement was a revolt of the intellect against existing conditions. In its entirety it is called the Renaissance. It was several centuries in gaining enough headway to break over the barriers that had been stretched across the path of progress. From time to time the more independent thinkers and the more gifted individuals had attempted to restore the practice of independent observation and thought, but, repeatedly, their efforts were suppressed by theological opposition. Finally, in the sixteenth century, through the efforts of men like Galileo, Descartes and Vesalius the method of scientific investigation was established. The renovation of intellectual life began as early as the thirteenth century and involved an expression of the human spirit in various directions—artistic, literary, scientific, etc. The artistic and literary development preceded the scientific, and it was not until the Renaissance was well under way that the scientific revival took place. In the latter was involved not only the progress of zoölogy, but all the benefits that have accrued from the development of modern science.

Among the actors in the scientific renaissance,

Andreas Vesalius (1514–1560), by reforming anatomy and thus placing morphological study on a new plane, stands closest related to zoölogy. His great illustrated work on the structure of the human body (*De Fabrica Humani Corporis*, 1543), based entirely on observation, not only restored anatomy but at the same time laid the foundations for the structural studies of animals. On account of the wide influence of this book of Vesalius', published in 1543, we must recognize it as one of the milestones of biological progress. It was his method of direct investigation that produced the greatest results.

Previous to Vesalius anatomy had been expounded from the desk chiefly by readings from Galen, a celebrated physician of the fourth century A. D. The strict adherence of Vesalius to observations and faithfully drawn sketches from actual dissections not only corrected many of Galen's statements but overthrew authority as a source of knowledge and replaced it by observation.

Some years later (about 1619) William Harvey, who is known for his discovery of circulation of the blood (1628), introduced experimental observation into scientific investigation. Thus the method of science was reëstablished and, on the basis of ob-

servation and experiment, scientific knowledge began to advance.

The zoölogy of the period was intermingled with medical science, especially with anatomy and physiology, and had no recognized existence as an independent subject. Although William Harvey investigated the structure of many animals, the embryology of the chick and of some mammals, zoölogy remained in the iatric condition of union with medicine. Out of this condition zoölogy emerged, not full fledged, but as a small offshoot of the medical sciences.

It was not long, however, in arriving at an independent position but the zoölogy of the seventeenth and eighteenth centuries had few modern aspects.

In the early years of the Renaissance Aristotle was translated, and later small independent advances were made by various writers as Wotton (1552), Jonston (1549–1553) and Aldrovandi (1599–1606). The most important zoölogical work between Aristotle and John Ray (the immediate prececessor of Linnæus), was that of the Swiss, Conrad Gesner (1516–1565). His *Historia Animalium* is a voluminous publication, four volumes appearing between 1551 and 1556,

and a fifth in 1587, twenty-two years after his death. In some editions it contains 4500 folio pages and nearly 1000 illustrations.

Through the renewal of observation the stream of science, so long held in check by wrong methods, was released, movement was started and the seventeenth century was notable for advance in independent observation. The microscope was introduced as a tool of investigation. The whole field of nature came rapidly under examination. Structural studies were applied to vegetables as well as to animals. Malpighi (1628–1694), Swammerdam (1637–1680) and Leeuwenhoek (1632–1723) investigated the structure of insects and of other simple animals producing valuable work on minute anatomy, on histology and on embryology. To notice these really important contributions in detail would unduly prolong the story. Accordingly, we pass to Linnæus (1707–1778) with whom systematic zoölogy may be said to have begun.

## CHAPTER V

## LINNÆUS AND HIS INFLUENCE

THE service of Linnæus to natural history was unique. He introduced clarity and system. The known animals and plants, ever increasing in number through the collections of travelers and naturalists, were in a confused state. They were known by local names in different sections of the same country and were differently designated in various languages. By adopting Latin as a uniform medium he elaborated a system of naming every production of nature in two words, a generic and a specific name, as *Felis domesticata*, for the domestic cat and *Canis familiaris* for the domesticated dog. The other members of the cat family as the lion, tiger, leopard, etc., were given the generic name of Felis and the specific name, in each case, distinguished the particular kind of Felis. In a like manner, the members of the dog family as the wolf, the fox, etc., are of the genus Canis but the specific attached to the generic name indicates the particular kind of anmal. The cat family as a whole was designated Felidæ and the dog family Canidæ.

Thus we have a simple and uniform system by

which all animals may be named. This system was adopted throughout the world, and by a happy stroke Linnæus gave to natural science a common language that remains in use to-day. The influence of this may be realized when we remember that the naturalists of all countries use identical names for the same animals and plants. He also simplified the problem of identification by giving terse descriptions, involving only the salient points by which animals and plants may be recognized.

His publication the *Systema Naturæ* which passed through twelve editions (first edition in 1735) is by no means a treatise on organization of animals and plants, but a methodically arranged catalogue with brief descriptions and their new names. The *Systema* embraces also a consideration of minerals.

Linnæus did not invent the binomial nomenclature but brought it into general use, and by common consent, zoölogists accept as the starting point for zoölogical names the tenth edition of the *Systema Naturæ* published in 1758. The botanists frequently use as a base line for names his *Species Plantarum* of 1753.

Although Linnæus made a lasting impression, he gave to natural history a one-sided development.

His followers were chiefly collectors and classifiers, who by interminable species-making brought zoölogy into disrepute from which it was rescued by Cuvier and others who emphasized structure, development, and physiology rather than mere classification.

Linnæus also defined species, which centered attention on the distinguishing characters of animals, and paved the way for the consideration of the origin of species that became so significant, under Darwin in the nineteenth century. In this particular Linnæus was preceded by John Ray (1628–1705) who was the first to introduce into natural history an exact conception of what is species.

Linnæus (Fig. 12) was born in Rashult, Sweden, 1707, the son of a poor Lutheran pastor. He was inattentive to ordinary studies, being engaged with his own thoughts and taking delight in collecting natural objects. He was regarded as dull and unfitted for an intellectual career. His father, in dispair, was about to apprentice him to a shoemaker when a doctor of the town recognized his unusual type of mind and pursuaded his father to promote his education. After many struggles with poverty, he was graduated from the University of Hardewyk in Holland in 1735 with the degree of Doctor of Med-

FIG. 11.—ARISTOTLE
(384–322 B. C.)

FIG. 12.—CAROLUS LINNÆUS
(1707–1778)

FIG. 13.—RUDOLPH LEUCKART
(1823–1898)

FIG. 14.—GEORGES CUVIER
(1769–1832)

icine. But he was destined for a university career, and after a few years of wandering in which he visited France and England, he was appointed professor at the University of Upsala and became one of the most widely recognized men of its faculty. His drawing power was great, during his residence the attendance at the University advanced from 500 to 1500 and his classes were attended by several hundred students. He sustained close personal relations with his students and his teaching gave a great impetus to the study of natural history. His disciples were for the most part men of smaller type and in their hands the study of zoölogy was lowered by their devotion to species-making while observations of a more important character on animals were neglected. Accordingly, the influence of Linnæus was not progressive. His chief service was to reduce to systematic form observations on the external and general character of animals and to supply the nomenclature that is in use at the present day.

As to personal appearance and human qualities this light-haired Swede was a short, thick man with large limbs, affable and easy of approach. He was vain and his self-esteem was greatly increased by the widely extended praise that had been given to his

work. He was impatient towards criticism and adverse comment of his work often threw him into a violent passion.

In 1907 occurred the two hundredth anniversary of his birth which was celebrated by the University of Upsala with appropriate ceremonies. At this time many articles were published about Linnæus that supply abundant reading matter regarding his life and work. To mark this celebration there was published a facsimile reproduction of the first edition of the *Systema Naturæ*—a folio of eight pages—containing the systematic arrangement of the "three kingdoms" of nature embracing minerals, plants and animals. This interesting document is readily accessible in the book market.

A splendid offshoot of the natural history of Linnæus is Ecology—the study of organisms in relation to their surroundings. This has wider affinities but is related to natural history. For convenience we may also place in this wide territory the Geographical Distribution of Animals.

The Linnæan system of classification had grave defects. It was not founded on a knowledge of the comparative structure of animals and plants, but in many instances upon superficial features that were

not distinctive in determining their position and relationships. His system was essentially an artificial one, a convenient key for finding the names of animals and plants, but doing violence to the natural arrangement of those organisms.

To do justice, however, to the discernment of Linnæus, it should be added that he was fully aware of the artificial nature of his classification. A real natural system, founded on the true affinities of animals and plants as indicated by their structural characters, he regarded as the highest aim of classification. But, he never completed a natural system, learning only a fragment.

Even the larger groups of animals were extended and much modified by Cuvier, by von Siebold, by Leuckart and by others. As to the larger divisions of animals and plants, Linnæus recognized only classes and orders. Then came genera and species. He did not use the term family in his formulæ; this convenient designation having been introduced, in 1780, by Batch.

The first modification of importance to the Linnæan system was that of Cuvier, who proposed (1815) a grouping of animals based upon a knowledge of their comparative anatomy. He declared that

animals exhibit four types of organization (Vertebrata, Mollusca, Articulata and Radiata) and his types were substituted for the primary groups of Linnæus.

But naturalists were not long in discovering that the primary divisions of Cuvier were not well balanced, and, indeed, that they were not natural divisions of the animal kingdom.

The group Radiata was the least sharply defined, since Cuvier had included in it not only those animals which exhibit a radial arrangement of parts, but also unicellular animals that were asymmetrical, and some of the worms that showed bilateral symmetry. Accordingly, Karl Th. von Siebold, in 1845 separated these animals and redistributed them. For the simplest unicellular animals he adopted the name Protozoa, which they still retain, and the truly radiated forms, as starfish, sea-urchins, hydroid polyps, coral animals, etc., were united in the group Zoöphyta. Von Siebold also changed Cuvier's branch, Articulata, separating those forms, such as crustacea, insects, spiders, and myriopods, which have jointed appendages, into a natural group called Arthropoda, and uniting the segmented worms with those worms that Cuvier had included in the radiate

group, into another branch called Vermes. This separation of the four original branches of Cuvier was a movement in the right direction, and was destined to be carried still farther.

Rudolph Leuckart (Fig. 13), the distinguished zoölogist of Leipsic, following the lead of von Siebold made further modifications. He split von Siebold's group of Zoöphytes into two distinct kinds of radiated animals: the starfish, sea-urchins, sea-cucumbers, etc., having a spiny skin, he designated Echinoderma; the jelly-fishes, polyps, coral animals, etc., not possessing a true body cavity, were also united into a natural group, for which he proposed the name Cœlenterata.

From all these changes there resulted the seven primary divisions—branches, subkingdoms, or phyla—which with small modifications are still in use. These are Protozoa, Cœlenterata, Echinoderma, Vermes, Arthropoda, Mollusca, Vertebrata. These seven phyla are not entirely satisfactory and there has resulted from more careful analysis a multiplication of subkingdoms and a redistribution of forms as in the case of the brachiopods, the sponges, the tunicates, etc.

A tabular view showing the modifications made in

the larger groups of animals will be helpful at this point.

| Linnæus | Cuvier | Von Siebold | Leuckart |
|---|---|---|---|
| Mammalia (Mammals) | Vertebrata (Embracing five classes: Mammalia, Aves, Reptilia, Batrachia, Pisces) | Vertebrata (Embracing five classes) | Vertebrata (Five classes) |
| Aves (Birds) | | | |
| Amphibia (Amphibia and Reptiles) | | | |
| Pisces (Fishes) | | | |
| Insecta (Including Crustacea, etc.) | Mollusca | Mollusca | Mollusca |
| Vermes (Including Mollusca and all lower forms) | Articulata..... | Arthropoda<br>Vermes | Arthropoda<br>Vermes |
| | Radiata..... | Zoöphyta<br>Protozoa | Echinoderma<br>Cœlenterata<br>Protozoa |

Biological progress (outside the changes in classification) from Linnæus to Darwin, although details were greatly multiplied, proceeded by definite steps. Linnæus and his successors were concerned with the organism as a whole, the external appearance, colors, spots, the horns, the hoofs, etc. The next distinct step was that taken by Cuvier and his school. Instead of the complete organism, the organs of which it is composed became the chief subject of analysis. The organism was dissected, the organs were examined and those of one kind of animal were compared with another. This started the line of comparative anatomy which played a much more important part in the development of zoölogy than work of the Linnæan type. After the organs were investigated the tissues came under review and, then, with more

incisive inquiry, the cells composing the tissues became the object of investigation. These progressive steps of analysis, from the organism, to organs, to tissues and cells finally culminated in the recognition of protoplasm the actually living substance of all animal (and plant) organization.

Knowledge of the physiological side of animal life had a parallel development. In the period of Linnæus, the physiology of the organism was pursued by Haller and his school; following this the physiology of organs and tissues was advanced by J. Müller, Bichat and others. Later, Virchow investigated the physiology of cells, and Claude Bernard the chemical activities of protoplasm.

## CHAPTER VI

## CUVIER AND STRUCTURAL ZOÖLOGY

After Linnæus had founded natural history and started activity in collecting and classifying animals zoölogy was soon in ripe condition for a new departure. The method of Linnæus brought about a general familiarity with the animal kingdom, but so long as studies were confined to externals and to the organism as a whole no deep-seated advance could be made.

Cuvier now came forward, and by a more incisive analysis, he placed emphasis on the study of structure as the key to the knowledge of animal life. When structure is pursued to its limit, by embracing microscopic as well as gross anatomy and the process of development, it makes a very important division of zoölogical study. This is structural zoölogy or comparative anatomy. The combination of the various studies that fall under this head are commonly designated morphological studies and the term morphology is used to embrace them all.

In order to complete the picture of animal life there is needed the complementary division of

physiological studies. Thus Physiology and Morphology are the two chief divisions of Zoölogy. We must remember that there was concurrent progress in these two departments but for clearness they must be separately considered.

Cuvier (1767–1832), (Fig. 14), although he had his forerunners, may be said to have founded comparative anatomy about 1805, and his influence dominated zoölogy for the first third of the nineteenth century. After attendance at the Carolinian Academy, at Stuttgart, in order to add to his slender purse, he accepted employment as private tutor to the sons of the Count d'Héricy. This took him to the sea coast near Caen in northern France. Having time at his disposal, with eager enthusiasm he set himself to become acquainted with the structure of marine animals (especially mollusca). The results of his investigations were sent to Paris for publication and this served to bring him to the notice of the working naturalists of the French metropolis. In particular, Lamarck and Geoffroy Saint-Hilaire connected with the Royal Garden (*Jardin du Roi*, later the *Jardin des Plantes*) gave a hospitable reception to his work and extended a helping hand. He was invited to come to Paris to connect himself with the

Jardin du Roi, and here he developed the Natural History Museum and gained recognition. Paris was thereafter his home and the scene of his triumphs.

His was an attractive personality and as he threw himself into his work with enthusiasm and well-directed industry, he gained power, and soon forged ahead of his companions in research. He was a favorite of the Emperor Napoleon and by him was made head of the educational system of France. He became a legislator and, finally, a Peer of France, but with all his public duties he remained faithful to his love of zoölogical science and continued to work in that field.

After his extensive treatise on comparative anatomy (1805) he published, in 1815, his well-known book on the Animal Kingdom (*Le Règne Animal*). In this he divided the animal kingdom into branches (embranchements) on the basis of their structure, recognizing as stated in the previous chapter, four great types of structure, the radiate, articulate, molluscan and vertebrate. Although this classification has been superseded by a better one, the basis of structure employed by Cuvier was important and was used in further advances.

Comprehensiveness of view was a distinguishing

feature of Cuvier's mind. In his investigations he covered the whole field of animal organization from the lowest to the highest, and combining his results with what had been accomplished by earlier workers, he established comparative anatomy on broad lines as an independent branch of natural science.

Cuvier represents the beginning of that side of zoölogy that reached its highest development in Karl Gegenbaur (1826–1903) and Max Fürbringer of Germany, in Owen (1804–1892) and Huxley (1825–1895) of Great Britain, and in Joseph Leidy (1823–1891) and E. D. Cope (1840–1897) of the United States. His intellectual heirs in France were H. Milne-Edwards (1800–1885) and Lacaze-Duthiers (1821–1901).

Notwithstanding all his mental gifts, Cuvier was not able to appreciate the most important contribution made to zoölogy in his period, by his distinguished contemporary and fellow-worker, Lamarck. He became a strong opponent of the theory of organic evolution of which Lamarck was the founder (1801 and 1809) in its modern sense. How completely Cuvier's opposition served to hold in check the progress of this fruitful idea in France is well recognized.

His famous debate with Saint-Hilaire, in 1830, on the subject of unity of type involved the principles of evolution. Cuvier won the debate largely from skill as a debater and his personal magnetism. Posterity views the matter in a different light and reckons this opposition to Lamarck's views as one of the shortcomings of Cuvier.

His influence was so lasting that it prevented for many years a respectful hearing of the evolutionary idea in France, and she was the last of the highly intellectual nations to harbor as true the ideas of organic evolution. Frenchmen, however, have attoned for this to a degree by establishing in the University of Paris a Professorship of Evolution under the charge of Maurice Caullery, and have given a cordial, if somewhat belated, recognition to one of their foremost zoölogists—Lamarck.

Comparative anatomy, the subject founded by Cuvier, supplies some of the most obvious and convincing evidences of organic evolution. Rightly pursued it is a rich subject not only for facts but for ideas. It is the division of zoölogy most commonly used in the laboratory exercises of the present time.

Before leaving the consideration of Cuvier's contribution to zoölogy, it should be pointed out that he

recognized the fossil vertebrates of the Paris basin as being the remains of extinct animals, and he founded the science of vertebrate paleontology. Lamarck, whose researches were largely directed to the analysis of the invertebrates, also investigated the fossil remains of these lower animals and founded invertebrate paleontology.

As we shall see in a future chapter the investigation of fossil remains is a part of zoölogical study.

**Histology.**—The structure of organisms presents two phases, that which is discernible to the unaided eye and that revealed only by the microscope. The former is gross anatomy and the latter minute or microscopic anatomy. The study of the microscopic structure of the tissues is so important and offers so many problems, that a new division of structural zoölogy (comparative anatomy) arose under the name of histology.

This is the microscopic anatomy of the tissues. The brilliant Bichat (1771–1801) was a pioneer in the investigation of the tissues of animals but histology did not take form until later. The establishment of the cell-theory in 1839 gave a great impetus to this study, and histology in the hands of Goodsir, of England, Koelliker, of Germany, and Ranvier, of France,

took on new and important aspects. It is a subject in which all medical students are trained and reveals what may be called the physiological anatomy of the tissues. After the establishment of the cell-theory it became clear that organs do not perform their function as units but through their smaller elements—the cells.

The rise of histology is interesting, but to follow it specifically would involve too great detail. Among the many workers in this field we may select von Koelliker (1817–1905), (Fig. 15), as the typical histologist of the nineteenth century. He published a text-book of Histology in 1857 and, thereafter, for forty years he continued to make contributions to this division of science. His great book on the tissues (*Handbuch der Gewebelehre*) passed through several editions from 1870 to 1897. It was thoroughly revised and brought down to date in the years 1894–1897.

The plant histologists, Grew and Malpighi, of the eighteenth century made interesting observations and published many sketches of the microscopic appearance of plant tissues. These sketches, which were faint foreshadowings of the cell idea, can be examined by those sufficiently interested to look up the works of Grew and Malpighi.

Leydig (1821–1908), in 1864, applied histology to insects and other invertebrates.

Virchow developed a line of abnormal histology which figures now under the name Pathology. Thus structural studies of the tissues under the microscope have given rise to normal histology and abnormal (pathological) histology or pathology.

## CHAPTER VII

## THE RISE OF EMBRYOLOGY

After the comparative anatomy of Cuvier was well under way came the establishment of embryology in which von Baer (1797–1876) was the central figure. In 1828, by the publication of his detailed observations on the development of the chick and other animals (1834), he established the germ-layer idea and carried the science of the development of animals to a high level.

Embryology is supplemental to comparative anatomy and in its present stage of development is to be classified as a morphological subject. It is not possible to appreciate in its full meaning any structural problem of zoölogy without the assistance of embryological study. The adult condition of an organism is the result of a series of changes, it is, in fact, the last step in a long series of modifications that have occurred in the process of building the body from the single-celled condition of the egg to its completed state. These modifications are so profound that often the affinities of the animal cannot be recognized in the modified state, and we

must go backwards and follow the embryological record to see where the modifications of structure occurred.

The most unexpected and most illuminating experiences come from this source. In the embryos of higher animals are found many traces of former ancestral conditions. Evanescent organs as gill-slits (with appropriate circulation) occur in all higher animals including the human body. The gill-slits of birds and mammals are transient and never come to functional use. But their presence is indubitable, and we begin to realize that they are clues to the structural features of ancestral forms. They have been handed along by heredity and although not rising to a functional condition, they exist as hereditary survivals from the days when the ancestors of birds and mammals were aquatic and had use for gill-slits in respiration. The presence of rudimentary teeth in the jaws of the embryos of toothless whales have the same significance.

Besides the transitory hereditary survivals, there are many rudimentary organs such as rudimentary ear muscles, tail muscles and the vermiform appendix of the human body which are interpreted in a similar way.

It becomes apparent, that in the course of development there is an embryological record impressed upon the organism, embryological study reveals this record and its interpretation is part of the task of the anatomist. Embryology is of great importance in zoölogy as giving clues to the relationship of animals and affording data for the recognition of their line of descent.

Von Baer (Fig. 16), the founder of modern embryology, was a man of superb mental endowment, unusual in the way in which he combined accurate observations with sane and fruitful generalizations. His "reflections" on the general features of the development of animals are still of value. His book on The Development of Animals (*Entwickelungsgeschichte der Tiere-Beobachtung und Reflexion*) is one of the great biological classics. He had finished his embryological investigations in 1828, at the age of thirty-one, and lived thereafter for forty-eight years. At the time of the publication of his treatise on embryology he was a professor in the University of Königsberg, but soon retired to look after his estates in Russia. He made no further contributions to embryology but became known for investigations in meteorology, anthropology, etc. An autobiography,

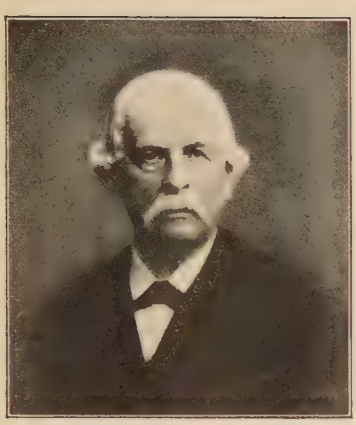

FIG. 15.—ALBRECHT VON KOELLIKER
(1817–1905)

FIG. 16.—KARL ERNST VON BAER
(1792–1876)

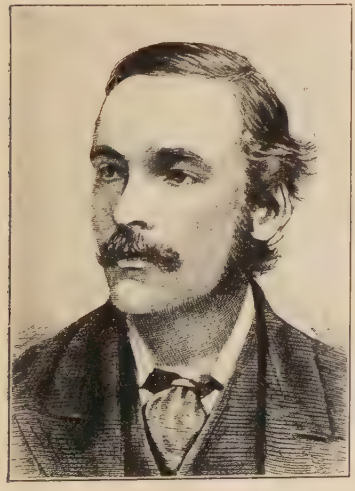

FIG. 17.—FRANCIS M. BALFOUR
(1851–1882)

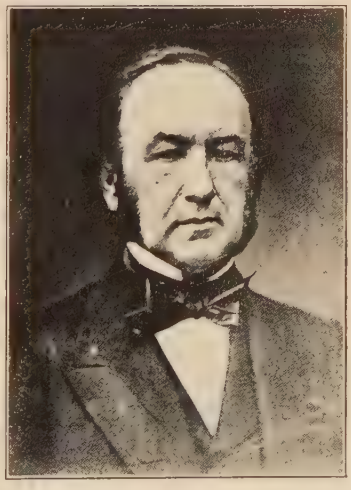

FIG. 18.—CLAUDE BERNARD
(1813–1878)

published in 1864, gives an interesting account of his mental development.

Between von Baer and Balfour (1851–1882) under whom embryology took on modern aspects, the observations on the development of animals were greatly multiplied. Activity was increased after the announcement of the cell-theory (1839) and embryologists began to see more clearly the significance of the germinal elements and the germ-layers.

It was determined that the egg and the sperm are single cells, the final step in reference to all eggs being taken by Gegenbaur in 1865. The three germ-layers common to all animals above the Cœlenterates (Hydra, Hydroids, Jelly-fish, etc.) were shown to be essentially alike as to origin and to give rise to the same kind of tissues in the different animals. In the light of embryology, all animals were seen to be related through ancestral lines and to be united on the broad plane of similarity of origin and development. Von Baer had already indicated this, but it was in the period between him and Balfour, that this great truth became better illustrated and took hold on the minds of embryologists and influenced their investigations.

Balfour (Fig. 17) now comes upon the scene and

does eminent service. Up to this time the investigations of the embryology of animals, both invertebrates and vertebrates, had resulted in a vast accumulation of monographs and scientific memoirs. These publications were scattered in technical periodicals, in the special publications of learned societies, etc.

Balfour gathered these researches, read, digested and published the results in a unified picture of the science of embryology. He clarified as well as unified the subject and produced a comprehensive book on comparative embryology that contained the substance of what was known regarding the development of all animals from the lowest to the highest. Balfour was especially gifted with the power of discriminating analysis and charm of expression. His book, of priceless value to embryologists, was published in two volumes, 1880–1881, under the title of *Comparative Embryology*.

Just after completing this monumental work while on a journey to the Alps for recuperation he met his death by slipping with his guide from one of the Alpine passes.

Since 1881 the science of embryology has developed rapidly. There has been great refinement of

observation and of technique. Studies have become more intensive such as following the cell-succession from the egg step by step until the germ-layers are established, further investigations into the mechanism of development, the nature of fertilization and the study of the behavior of the chromosomes of egg and sperm. The subject has also become experimental.

It has become too vast for a single publication to embrace the embryology of invertebrates and vertebrates, and, as a consequence, we have the standard embryology of invertebrates by Korschelt and Heider and many volumes on vertebrate embryology. There are also those on a single animal, as Lillie's *Development of the Chick*, and those on the development of the Human Body such as the volumes by McMurrich, Keibel and Mall, etc.

The great reference book on vertebrate embryology as a whole is the comparative and experimental embryology of Vertebrates, in six volumes, under the editorship of Oskar Hertwig, assisted by a large number of collaborators.

Among living and recent embryologists should be mentioned: Oskar Hertwig (b. 1849) of Berlin; Wilhelm His (1831–1904) of Leipsic, whose researches on

the development of the nervous system, the origin of nerve fibers and the embryology of the human body are important; and the late Charles Sedgwick Minot (1852–1914) (Fig. 22). The last named biologist, of dignified yet gracious personality, is remembered for the wide and stimulating influence which he exerted upon the development of biological research in the United States. He was a prolific writer, his best known books being *Human Embryology* and *A Text Book of Embryology*, which take high rank. He established at the Harvard Medical School a comprehensive collection of prepared sections of the embryos of all classes of vertebrate animals. Under the name of the Harvard Collection these are generously placed at the service of investigators and have been the source of sketches for a large number of embryological papers.

The notable collection of human embryos accumulated on the Carnegie foundation by Professor Franklin P. Mall (1862–1917), of John Hopkins University is also available for reference and for the use of investigators.

## CHAPTER VIII

## GENERAL PHYSIOLOGY AS A DIVISION OF ZOÖLOGY

THE study of structure and development is not enough to acquaint us with the essential features of an animal. The most significant thing about animal mechanism is that it is endowed with life and we should observe the principal activities of the mechanism along with its structure. As before indicated, morphology and physiology represent the main divisions of zoölogy. While physiology as a science has advanced to great proportions and to a position of independence, nevertheless general physiology of animals is a part of zoölogy. It will, therefore, be appropriate at this point to engage in a consideration of the rise of physiology without attempting to separate general physiology of animals from the main current.

Morphology and physiology had a parallel development. Just as Vesalius renovated structural studies so Harvey by demonstrating the circulation of the blood gave life to a new physiology.

This demonstration of the circulation had more

far-reaching consequences than appear on the surface. It was not merely showing that the blood moves in a circuit, it also opened up the entire question of the part played by the blood in the animal economy. This is basal to the understanding of physiology.

The tissues are bathed by the blood current. It is the carrier of oxygen to the tissues of the body; into its stream are diffused all the products of digestion, of secretion, and of excretion; by its circulation it distributes nourishment to the most remote parts of the body and brings back the products of worn out tissues for elimination by the kidneys, the lungs and the skin. Accordingly, a proper conception of the circulation was a necessary preliminary for the progress of physiology.

The classic book of Harvey (Fig. 30) on the circulation of the blood (*De Motu Cordis et Sanguinis*) was published in 1628, but he had been giving the substance of it in his university lectures since 1619.

In the time of Harvey, however, physiology had not fully emerged—it was still intermingled with medical studies. It was not till the following century, through the work of Haller, that it took its place as an independent subject to be pursued for its

own sake and not necessarily for its applications to medicine.

Haller's elements of physiology (*Elementa Physiologiæ*) published in 1758 was the first comprehensive treatise devoted exclusively to that subject. After Haller physiology, now opened for investigation, grew rapidly. We must remember, however, that Harvey was the pioneer who introduced experimental study into biological science. The work of Haller greatly broadened the field and encouraged physiological experimentation.

From the time of Haller we pass to the nineteenth century. In the opening year of that century was born a man, Johannes Müller, who exercised great influence not only on physiology but upon the whole field of biological science. Verworn says of him: "He is one of those monumental figures that the history of every science brings forth but once. They change the whole aspect of the field in which they work, and all later work is influenced by their labors." Although Müller was professor of Physiology at Bonn, and later at Berlin, he was also an anatomist and, perhaps, more of a morphologist in his methods of investigation than physiologist. He was great in his general influence. He had an un-

usual faculty for inspiring enthusiasm in his students and many of them, as Helmholtz and others, have borne testimony of his immense influence in giving them an outlook on life and inspiring them to their highest endeavor.

Müller (1801–1857) (Fig. 19) made physiology broadly comparative. He brought into it all the means of advancing the knowledge of animal organization—morphology, the microscope, chemistry, experiment, etc. He included psychology as a new departure in the study of physiology.

But to the Frenchman Claude Bernard (1813–1878) belongs the chief credit as the innovator of experimental physiology. With the exception of Ludwig, no other physiologist of his period can be compared with him in the experimental field. In his *Introduction to the Study of Experimental Medicine* (*Introduction à l'étude de la Médecine Expérimentale*—1865), he summed up what he had for years been teaching in his university lectures, and this remains the standard contribution on the aims and methods of experimental physiology.

Bernard's position in the history of physiology has not been fully appreciated by biologists. He was the foremost representative of physiology of his period.

FIG. 19.—JOHANNES MÜLLER (1801–1858)

Notwithstanding the overshadowing figure of Müller and his tremendous general influence, Bernard's scientific contributions to physiology are of a higher order. A careful reading of Bernard's investigations and lectures are serving to advance him into the foremost rank. Although his great skill as an experimenter and his exposition of experimental physiology in his *Introduction* entitle him to eminence, he will be longest remembered for several epoch-making discoveries.

Of these discoveries only two will be mentioned. First the discovery of the occurrence of glycogen in the liver—one of the first and most complete studies of internal secretions. That the liver forms animal starch (glycogen) as well as bile was a brilliant conclusion which was demonstrated by well thought-out experiments. Bernard was notable for the way in which he directed his experiments towards definite ends. He was no blind experimenter who reached into the unknown by tentative gropings, but first he made a crucial mental analysis of his problem, and then devised experiments for its investigation.

His discovery of vaso-motor nerves—both dilators and constrictors—was another piece of experimentation of broad application in physiology.

It will clear matters to remember that Bernard used the designation experimental medicine as synonymous with physiology, accordingly his *Introduction à l'étude de la Médecine expérimentale* was a treatise on experimental physiology.

It was Bernard (Fig. 18) who also gave a definite position to general physiology which, as before stated, is a division of biological study. His now classic *Phenomena Common to Animals and Plants* (*Leçons sur les phénomènes communs aux Animaux et aux Végétaux*), published in 1878, was the first treatise devoted to consideration of the vital activities of plants and animals.

Physiology established on the broad foundations of Bernard and Müller developed along two independent pathways—the physical and the chemical. We find a group of physiologists, among whom Weber, Ludwig, Du Bois, Reymond and Helmholtz were noteworthy leaders, devoted to the investigations of physiological facts through the application of measurements and records made by mechanical means. With these men came into use the time-markers, the kymographs, and other ingenious methods that have been adopted by Zoölogy, Physics and other sciences. The investigation of vital activities by means of

graphic records made by instruments of precision has come to represent one especial phase of modern physiology.

The other marked line of physiological investigation has been in the domain of chemistry, where Wöhler, Liebig, Kühne, and others have, through the chemical changes occurring in its body, observed the various activities that take place within the organism. Some of the more recent observations have made a particular feature of the study of chemical changes taking place within living matter. The prodigious development of organic and biological chemistry has shown the close interrelationship of chemistry, physiology and biology.

The physiological method has been much applied in zoölogical study. Besides the important investigations carried on by zoölogists under the title of "Experimental Morphology" there has arisen a recognized division designated experimental zoölogy which is chiefly physiological.

General physiology is so intimately related that all students of zoölogy should take occasion to become acquainted with Verworn's admirable treatise on *General Physiology*.

## CHAPTER IX

## THE ANIMAL KINGDOM

It is common phraseology to speak of the great province embracing all animals as "The Animal Kingdom." Linnæus employed the designations "Animal Kingdom," "Plant Kingdom" and "Mineral Kingdom" to indicate the three kingdoms of nature; and the title of Cuvier's general zoölogy was *The Animal Kingdom Arranged According to its Organization.*

One phase of zoölogy has for its aim to give a descriptive inventory of the animal kingdom. We should remember, however, that this is merely one aspect of zoölogy. In early times, it was the dominate feature of zoölogical study, but it is now subordinate in importance to those phases of the subject that deal with structure, development, physiology, habits, etc. The orderly arrangement of animals into natural groups of different rank should be the outcome of a study of their structure and life histories.

In the time of Linnæus, the classification of animals was based on observations of the external resemblances and differences and, later, the internal

structure was taken into account for the same purpose. At the present time, however, and ever since the doctrine of descent began to be accepted, naturalists have had a better criterion for determining relationships. Animals exhibit relationships because they have sprung from a common stock. The members of a natural group resemble each other in structure because they have a genetic relationship and those that are closest allied have a closer kinship.

When the entire animal series is spoken of as the Animal Kingdom, the large natural subdivisions of the territory formerly were called subkingdoms, but, at present, the designation commonly employed for each subdivision is Phylum (from the Greek *phylos*, a tribe). There is no agreement among zoölogists as to the number of phyla into which the animal kingdom should be divided. "Some authorities recognize only eight, while others maintain that there should be as many as twenty or even more." Such extensive subdivision of even the primary groups is probably justified on technical grounds, but, as Richard Hertwig has remarked: "In this way groups poor in species and of little importance in a general account of the animal kingdom are placed on the same basis as the large and exceedingly important groups of

vertebrates, arthropods and molluscs and thus obtain, especially in the eyes of the beginner, an importance which does not belong to them."

For our present purpose, it will be sufficient to enumerate and briefly characterize the ten phyla which embrace nearly all animals except those of somewhat uncertain position. While merely the phyla are mentioned here, it is to be understood that the division of these large groups into classes, orders and families brings us by groups of different rank to genera and species. The latter divisions supplying the generic and specific name by which individual animals are known.

**I. Protozoa.**—The simplest microscopic, usually aquatic, single-celled animals. In these animals, the manifestations of life are reduced to their simplest expression and a study of them is the best introduction to the more complex animals and also the best introduction to general physiology. Certain forms are disease-producing or pathogenic, as the germ of malaria, of sleeping sickness, etc. Although very minute, certain kinds of protozoa commonly occur as fossils. Those producing shells of carbonate of lime making beds of chalk, and those forming shells of silica occurring in fossiliferous earths. The known

Protozoa number about 8500 living and 200 fossil species.

**II. Porifera.**—The sponges, chiefly marine animals composed of many cells surrounding pores and channels through which water circulates freely. Besides budding, they are reproduced by eggs and sperms. The soft living "sponge-flesh" is usually supported by spicules and, in different varieties, by skeletons of horny, calcareous or silicious material. The horny sponges are of commercial importance. The calcareous sponges and glass sponges are frequently found as fossils. Fresh water sponges, usually inconspicuous, are widely distributed but of no commercial value. Approximately 2500 living and 800 fossil species are known.

**III. Cœlenterata.**—A group of slightly complex animals embracing the fresh water hydra and numerous salt water forms, as the polyps, jelly-fish, coral-forming animals, etc. They exhibit a radial arrangement of parts and most of them possess peculiar stinging cells. The first distinctly developed nervous system and sense-organs appear in this group. Four thousand two hundred living and nearly 2000 fossil species are recognized.

The animals formerly grouped under the general

heading *Vermes* present diverse and often puzzling relations. It is now universally recognized that there is no natural group or phylum "vermes" but the title is often retained on account of its convenience. The title is justifiable only as a popular name for shape. The animals included under it do not form a natural group of related species and the general tendency is to split the group into at least three phyla,—the flatworms, the roundworms and the segmented worms or annelida. The brachiopod, which are so abundant as fossils (5000 species) are frequently classified as shelled worms; at other times, they are separated into an independent phylum, or are united with the bryozoa into a phylum *molluscoida*.

**IV. Platyhelminthes.**—This phylum of flatworms includes fresh water, salt water and land planarians and parsitic forms. The parasitic flatworms, such as tapeworms, liver-flukes, etc., are responsible for certain diseases of man and other animals. Four thousand six hundred species are known.

**V. Nemathelminthes.**—The roundworms or threadworms are chiefly small parasitic worms, living in the alimentary canal, the blood or the tissues of man and other animals. The hookworm, respon-

sible for much misery and shiftlessness among the "poor whites" of the south, is an example. Other common illustrations are: The harmless "Vinegar-eel";—the pin worm of the alimentary canal; the Trichinella, which imbeds itself in the muscles and comes from infected and imperfectly cooked pork; the Filaria, a blood parasite, etc. One thousand five hundred living species are recognized.

**VI. Annelida.**—The segmented worms embracing the earthworm, the leeches and others. Some forms burrow in the earth, others inhabit fresh water (leeches), and salt water (Nereis). About 4000 living species are known.

**VII. Echinodermata.**—Marine animals with a spiny skin or a calcareous test covering the soft parts. The sea cucumbers, the starfishes, sea urchins, sea-lillies, etc., belong to this group. They exhibit a radial arrangement of parts. Locomotion is usually by tube-feet connected with a characteristic water vascular system. There are known approximately 3000 living and 2600 fossil forms.

**VIII. Arthropoda.**—Contains the largest number of species of any phylum. Separated from all forms of worms by possessing jointed appendages. The phylum embraces several large classes as: (1) *Crus-*

*tacea*, lobster, crayfishes, shrimps, sow-bugs, etc. (2) *Insecta*, an enormous group containing about 400,000 described living and 5000 fossil species. Very interesting for exhibiting serial homology of the appendages. These structures, although all equivalent, and arising in the same manner, are, under certain conditions, transformed into jaws, antennæ, walking-limbs, swimerets, etc. The insects exhibit more clearly than any other animals the phenomona of metamorphosis such as the development of a worm-like larva through the chrysalis stage into the winged insect. These animals are also immensely interesting on account of their relation to the fertilization of flowers, their habits, their communal life and as disease carriers. (3) *Myriopoda*, centipeds, "thousand-legged worms," etc. (4) *Arachnida*, or spiders, notable as web-spinners. This class includes scorpions, Limulus (the king-crab) and others.

**IX. Mollusca.**—Slugs, snails, clams, oysters, squids, cuttle-fish, devil-fish, etc. Although the name mollusca is from the Latin *Mollis*, meaning soft, this applies only to the bodies of these animals; a large number of them secrete shells which circumstance makes them of frequent occurrence as fossils. About 60,000 living and 21,000 fossil forms are known.

**X. Vertebrata.**—The most highly developed animals, those above the simplest ones possessing vertebræ, but this feature is not common to all. Excluding Tunicates and Amphioxus, five classes are recognized: Fishes, Amphibia, Reptiles, Birds and Mammals. The latter class including man. There are about 30,000 living and a large number of fossil species.

Intermediate between the molluscs and the vertebrates are sea-squirts, or Tunicates. A phylum *Chordata* is frequently made to include the Tunicates, other primitive forms, and the vertebrates because all these animals are alike in possessing a notochord, a dorsal nerve-cord and gill-slits. The Tunicates number about 300 species.

There are several other groups of invertebrates of uncertain position but which are often elevated into the rank of phyla. If the Brachiopods are classed as shelled worms, the most important of the remaining forms are the *Bryzoa*. These are moss-like, incrusting animals, inhabiting both salt and fresh water, and numbering about 700 living and 1800 fossil species.

For a more detailed analysis of the animal kingdom, with sketches and consideration of the structure of types, consult the various manuals and text-books.

**The Animal Series.**—In a certain sense animals constitute a series, at the lower end of which are the simple Protozoa and at the upper end the Mammals. However graphic this conception may appear, it needs to be taken with proper qualifications. Animals do not by any means form a connected series. There is much overlapping of different groups and there are various perplexing offshoots—as in the case of the Echinoderms. Animals constitute a series in the sense that they have a common ancestry and that the higher forms are derived from the lower by a process of descent, but adaptations to different conditions of life have brought about many diversities. The significant point is that they do not stand as separate creations but are all related structurally, physiologically and psychologically.

We may say, the most striking general feature of an animal is that it has not arisen independently, but that it exhibits a genetic similarity with other members of the animal kingdom. The recognition of the common genealogy of animals led to the doctrine of organic evolution. It also prepares us to understand that the study of a few selected types from the different natural groups, with an analysis of their structure, their life histories and their relations to sur-

rounding conditions, may serve to open the whole field of zoölogy. Huxley attempted to do this by the use of a single animal in his famous *Introduction to the study of Zoölogy* based upon the study of the Crayfish in all its essential relations to other animals and to nature at large.

The study of types is a good procedure, but how to avoid having this method lead merely to accumulation of a certain set of facts regarding animals is a matter of much concern, since that has been the result, in so many cases, of holding exclusively to this plan. As stated in an earlier chapter, what is lacking in this method is concurrent attention to the background of the subject—information about the conditions under which the subject developed, the circumstances that made possible its advances, the men who accomplished results and an orderly though brief account of the steps in its development.

**The Number of Animals.**—The number of known animals is ever increasing by descriptions of new species. Aristotle mentioned about 500 but probably knew more. Linnæus, in 1758, described 4236 species. About a hundred years later, Agassiz and Brown listed 129,530. In 1886, Ludwig's revision of Leunis's Animal Kingdom gives 273,220, and Pratt,

in 1911, enumerates 522,400. This represents only the named species of living animals and is far short of the actual number. In Pratt's enumeration there are 360,000 insects. We are to understand that the number of living species is much larger since there are many that have not been described and classified.

## CHAPTER X

## ZOÖLOGY OF FOSSIL REMAINS

THERE is one large division of zoölogy not yet touched upon—the study of the remains of extinct animals. This is obviously a department of zoölogy although it is more frequently placed with geology under the name of paleontology. The extinct animals were ancestors of those now living and many revelations are found by studying their fossil remains. The fossil remains of animals are so numerous and cover such a long range of time, that we have preserved in the rocks not only a picture of the succession of animal life on the globe for many centuries, but, also, records of the transmutations or the structural changes they have undergone. These open such a wide sweep of observation that they are of incalculable value in the study of zoölogy.

It is estimated that if the fossil bearing rocks were accumulated in one series they would measure more than forty miles in thickness and represent a period of several millions of years in their formation. Examination of the fossils from the lower rocks shows that for many æons there were no vertebrate animals, and,

that for the duration of many additional æons, the only living vertebrates were Fishes. From the fishes were gradually evolved the amphibians, the reptiles, the birds and, finally, the mammals. All these changes requiring immense stretches of time took place before the advent of man.

From time to time the fossil series exhibits interesting connecting links such as the curious tailed and toothed bird, the archæopteryx, showing structural relations between reptiles and birds.

The science of fossil remains is not only an offshoot of zoölogy but as before stated it was founded by zoölogists; Cuvier being the recognized founder of vertebrate and Lamarck of invertebrate paleontology. This science was extensively developed by Zittel, the paleontologist of Munich, and by Cope (Fig. 20), Leidy (Fig. 21), and Marsh in the United States as well as by more recent workers.

Extensive progress has been made within the past twenty-five years in observations of the fossil animals and among other advances the genealogy of several living families of mammals has been traced. Notable studies have been made on the ancestry of Camels, Elephants, etc. The most thoroughly known ancestral history is that of the horse. The zoölogical

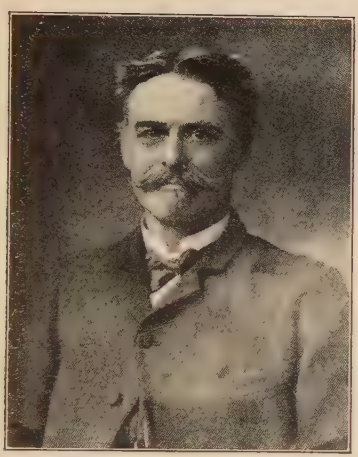

FIG. 20.—E. D. COPE (1840–1897)

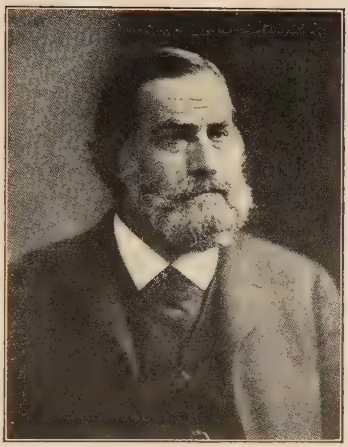

FIG. 21.—JOSEPH LEIDY (1823–1891)

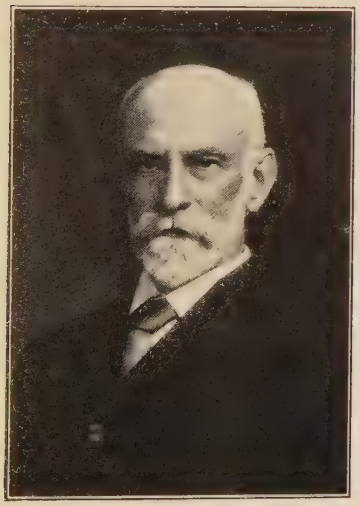

FIG. 22.—CHARLES SEDGWICK MINOT (1852–1914)

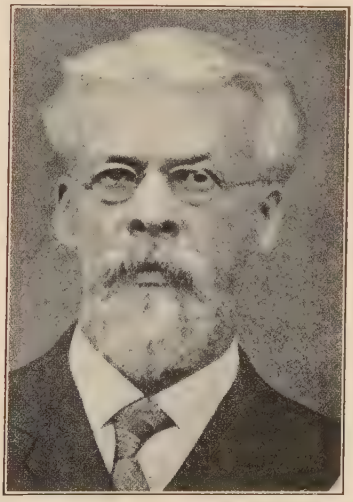

FIG. 23.—CHARLES OTIS WHITMAN (1842–1910)

history of this animal is a hackneyed theme but, nevertheless, very convenient for reference. Although not old in comparison with the earlier animal life, a quite close series of fossil remains shows the development of the horse family through a period of 3,000,000 years. The earliest authenticated ancestor of this race began in the Eocene period with an animal having a four-toed limb in front and a five-toed one behind. About the size of a fox, this eohippus was the ancestor of the horse tribe. From this point, the descendants of the original forms show the structural modifications through which the family of horses passed, until we arrive at the recent horse with a single toe on both fore and hind feet, with the molar teeth modified and fitted for its food of grass and grain.

In the museum at Yale University and, notably, in the American Museum of Natural History in New York City, are preserved a large number of the fossil remains of these animals. The development was not that of a single kind of horse but parallel development of several varieties some of which have become extinct and others continued. It is a difficult problem to keep separate the straight line of ancestry of our modern horse, but the material now accu-

mulated enabled Professor Henry F. Osborn, and others, to separate the equus line from the other fossil horses and to indicate the direct line of descent.

From the zoölogical standpoint especial interest has centered about the fossil remains of man and of pre-humans that are throwing light on the question of human lineage.

The story of prehistoric man is imperfectly known, although sporadic explorations have already accumulated an interesting series of evidences bearing on the subject, such as primitive stone implements of human manufacture, crude sketches of extinct animals by prehistoric artists, and fossil remains of primeval man showing gradations in the shape and the capacity of skulls. All these correlated sources afford most convincing proofs of man's great antiquity. He has left traces of his occupancy of the earth, especially in central and southwestern Europe and in England, long before the dawn of the historical period.

The prehistoric stone implements are found associated with the bones of extinct animals in caves, and imbedded in the strata of soil and gravel that have remained undisturbed for many centuries. The stone implements are of three grades: Neoliths, the more

recent ones, carefully shaped with skill and artistic feeling; Palæoliths, very ancient, rude, but evidently shaped by design; and Eoliths, rough stone chips bearing evidence of use and indicating the existence of man of less developed skill. These latter implements carry the trace of a tool-making creature back into the Tertiary period.

Besides the stone implements there are many sketches of extinct animals by prehistoric artists, scratched on bone, ivory, horn, slate and on the walls of caves. The inference to be drawn from these sketches is that man was alive in Central and Southwestern Europe when the hairy mammoth and the reindeer occupied the same territory. The crude sketches of palæolithic man, just referred to, merge by gradations into the more carefully drawn, and sometimes colored sketches, of Neolithic man. Those of the cave of Altimera, in Spain, are very notable products of Neolithic artists.

The range of discovery of fossil human relics gives evidence of a wide geographical distribution of primitive races during palæolithic times. Variations in the degree of skill in the manufacture of stone implements, as well as in other particulars, have brought to archæologists the recognition of different

culture periods, which are well exhibited in different parts of France and Central Europe. No less than six culture-periods of palæolithic man are known, indicating that the prehistoric period of human development was far longer than the entire historic period.

It is, however, to fossil remains of primitive man that we must look for evidences of structural changes that have taken place in the human frame.

Of all the bony parts, the skull is the most interesting for comparison, since its size and configuration indicate in a general way the degree of development of the brain, and, as a consequence, the relative grade of intelligence.

One of the most famous documents of man's ancestral history is the well-known Neanderthal skull, discovered in a cave near Düsseldorf in the valley of the Neander, in 1856 and first described in 1857. It is now exhibited with other parts of the skeleton in the provincial museum at Bonn on the Rhine. The inferences drawn from this very ancient skull, with its low receding forehead, showing small development in the region of the higher mental faculties, created a sensation, and great opposition was developed in allowing the discovery to rank as an evidence

of primitive man. But its importance has been enhanced by the discovery of a long series of similar skulls.

In 1886, came the discovery in the Cave of Spy, Belgium, of two skeletons with the same structural features as those of the Neanderthal remains, and, since that time, the discoveries of numerous similar relics have established the existence of a Neanderthal race living in the middle of the palæolithic period. The more notable members of the Neanderthaloid series embrace: the human remains of Krapina, in Croatia, found in 1899–1904, and consisting of parts of the skeletons of ten persons from infancy to old age; the skeletal remains of La Chapelle aux-saints and of Le Moustier.

In August, 1908, there was discovered in Southwestern France, by well directed efforts of French archæologists, a very interesting skeleton of the Neanderthal type, and now known as the man of La Chapelle aux-saints. This is the skeleton of an old man with an almost complete skull, and a lower jaw lacking some of the teeth. Since the comprehensive analysis of these remains, published by Boule in 1913, this is the most thoroughly known skeleton of the Neanderthal race and may be taken as a type. Be-

sides the structural features of the bony parts, it is interesting to note that the casts of the interior of the cranium show the surface features of the brain. As compared with the brain of modern man, it is small in the region of the frontal lobes and shows a greater simplicity in the pattern of the convolutions.

A somewhat more primitive type was discovered a few months earlier (March, 1908) at the famous station of Le Moustier. It is the skull of a young person and valuable for comparison.

These aboriginal people represent one link of the chain of human ancestry, and they were followed by a higher developed type of primitive man before the dawn of history and the emergence of the modern type.

A much more interesting circumstance is that the Neanderthal people were preceded by more primitive pre-humans. There are known at present three examples of remains that are distinctly pre-Neanderthaloid. The first to be discovered, and also the most primitive pre-human species known, is represented by portions of the skull, and of the leg bones, found in Central Java by the Dutch surgeon, Dubois, during the years 1891 and 1892, and made known in 1894. These remains were found in Ter-

tiary deposits and were christened with the name of *Pithecanthropus Erectus*. The capacity of the skull, 930 cubic centimeters, precludes the conclusion that it belongs to the series of anthropoid apes—the largest cranial capacity of apes, living or fossil, not exceeding 600 cubic centimeters.

The second pre-Neanderthaloid is the perfect lower jaw with all the teeth, discovered in 1907 in the sands of Mauer, near Heidelberg. These deposits belong to the lower Quarternary, and since the discovery of the Heidelberg jaw it is claimed that Eoliths have been discovered in the same layer. The jaw, while distinctly human as to characteristics of the teeth, is very primitive. The creature to which it belongs has been designated *Homo Heidelbergensis*.

The most recent discovery of pre-human remains comes from England. At Piltdown Common, in Sussex, in 1912, there was unearthed a skull, with parts of the lower jaw and teeth, that fits into the series of the pre-Neanderthaloids. It has been suggestively named the dawn man (*Eoanthropus Dawsonii*).

Above the Neanderthal race come the numerous fossil remains of Neolithic man, merging by struc-

tural gradations into those of recent type. The skeleton of Mentonne, that of Combe Chapelle (1909), of Galley Hill (1895), the Crô-magnon race and other representatives are forms that connect palæolithic with recent man.

Putting these discoveries together we have an interesting series of gradations of skulls, leading one into the other, and covering a range of cranial capacity from 930 cu. cm., that of the Java man, to 1480–1555 cu. cm. that of the average white European. The Neanderthal skulls occupy an intermediate position with a cranial capacity of approximately 1400 cu. cm.

In tracing backwards from recent man, it is not to be assumed that the ancestral line breaks off abruptly. Even the Java man had antecedents, and it is natural to assume his derivation from an extinct Primate of the Earlier Tertiary deposits. Positive evidences are lacking, but the known presence of anthropomorphous Primates in the Miocene of France offers a possible suggestion. Paleontological discoveries have supplied the line of genealogy of several families of mammals, and if, on this basis, we assume that man and the anthropoid apes had a generalized ancestor, it is nevertheless clear that the

human and the simian lines have had an independent development for many centuries. There has been no crossing of the lines since Tertiary times.

The derivation of man from an extinct Tertiary Primate seems already to be well authenticated. Furthermore, the fossil records give evidence of the conditions under which the development of the higher races of animals began. By making plastic casts of the interior of the fossil skulls of Tertiary mammals, it has been determined that there was in that geological period a marked increase in the size of the brain. This circumstance was of the greatest importance both for progress and for perpetuity of certain kinds of animals. Those, in particular, whose increased intelligence enabled them to cope more successfully with the conditions of their existence, and to turn natural forces to their advantage, were continued and improved. In pre-humans the increase in brain surface led to the power of storing up impressions, and, finally, brought about a condition of educability which formed the starting point for marked improvement.[1]

[1] The above 14 paragraphs quoted from the writer's *Biology and Its Makers*.

## CHAPTER XI

## MAIN PATHWAYS AND RECENT TENDENCIES OF ZOÖLOGY

At this point it will be convenient to indicate the chief pathways by which the territory of zoölogical study has been entered and explored. Broadly speaking, the main highways of zoölogy are embraced under the following designations: *Structural Zoölogy* (Morphology), with its subdivisions—comparative anatomy, histology, embryology, and the study of fossil animals; *Systematic Zoölogy* (Natural History), comprising classification, ecology (the relation between animals and their surroundings), study of habits and geographical distribution of animals; *General Physiology* of animals, with animal psychology and animal behavior; *Experimental Zoölogy*, (which is more a method of general application than a subdivision), embracing Genetics, experimental morphology and similar branches; and, *Philosophical Zoölogy*, with organic evolution and related topics. In addition there are some miscellaneous divisions of smaller importance.

To bring these various subdivisions under bird's-

eye view with brief comments will help mark the pathways of the territory.

**Structural Zoölogy.**—The two broad aspects in the investigation of animal forms are morphological and physiological. Supplemental to one another, they embrace the statics and the dynamics of animals—the architecture and the function. Structural zoölogy (or morphology) is fundamental in providing a basis for physiological investigations. It includes topics dealing with gross and minute anatomy, with the process of building, or development of the body, and the study of fossil animals. Accordingly, we recognize its chief subdivisions as comparative anatomy, histology, embryology and paleontology (paleozoölogy).

*Comparative Anatomy.*—The study, broadly comparative, of the structure of animals, well adapted for the early stages of laboratory observation, usually pursued by an examination of types of animal life from the lowest to the highest. The microscope is necessary for the examination of the whole group of protozoa and for other minute animals such as rotifers, microscopic crustacea, etc.

Comparative anatomy is chiefly the structural study of animals as to their organs and systems of

organs, as the digestive system, the circulatory system, the nervous system, etc. It aims to establish homologies between organs by tracing the origin and modifications of structures occurring in series of animals.

*Histology.*—By the microscopic study of the tissues composing the organs we come to histology. This reaches a deeper level of morphological analysis than comparative anatomy. In its full scope, it distinguishes the cells as well as the tissues, and cytology is an offshoot of histology. The study of cells, however, has assumed such importance and opened so many new questions that cytology stands out as an independent division. The arrangement, the form and staining qualities of cells often do much to show the use of tissues, and, therefore, cytology has its physiological side.

*Embryology.*—This likewise has become a broad subject including observation of all stages of development from the egg to hatching—or birth. Among its especial topics come the analysis of the germinal elements, the nature of fertilization, the formation of the germ-layers, the physical basis of heredity, the histological differentiation (histogenesis) of tissues, etc.

*Paleontology.*—The study of fossil animals (paleozoölogy) is a division of morphology since the investigation of the physiology of fossil remains is not practicable. That part of it that deals with animal forms is zoölogical rather than geological. It is a study of the succession of animal life on the globe. In passing, it should be remarked that the succession of plant life (paleobotany) has been in recent years the field of very notable advances.

**Systematic Zoölogy.**—Deriving its name from the systematic arrangement of animals as first accomplished in the Systema Naturæ of Linnæus. Since classification is based largely on structural features, it would appear that in its recent scientific aspects, it should be the outcome of morphological study—and such is the case. But this was not so in earlier times—Systematic Zoölogy had large development before morphology pushed into prominence. It arose out of the old natural history of Linnæus. The designation natural history is, however, more comprehensive than classification. It represents the kind of study of animals to which the name zoölogy was applied after the Renaissance. After the rise of morphology, natural history continued to develop and took on modern form. To this division belongs

the classification of animals for which the modern name is taxonomy. From it arose the study of field zoölogy, with such offshoots as *ecology*, the study of habits, and, of the geographical distribution of animals.

Work in *ecology*—the study of the relations between animals and their surroundings—has been very active in the last decade. There has been developed an extensive technique for experimental observation of animals, special societies have arisen, text-books and periodicals for the publication of results of ecological study have been started. Geographical distribution of animals is also allied to natural history.

**General Physiology.**—The most significant thing about an animal is that it is endowed with life and the analysis of those vital processes that are an expression of its life, should go hand in hand with the study of its structure. Zoölogy that is limited to study of the architecture of animals manifestly is inadequate. General physiology of organisms is as much a part of zoölogy as is morphology but it is not so frequently utilized in courses of study. The subject as related to zoölogy embraces a general consideration of the principles upon which all physiological

operations depend—responses to stimuli, fermentation and digestion, circulation, secretion, excretion, reproduction of animals, etc. But physiology is also an independent science, pursued for its own sake, and statements like those just made are not to be taken even to imply that physiology in this sense is a part of zoölogy. A parallel situation exists in reference to anatomy, which is a separate science, whilst the comparative anatomy of animals is a major subject of zoölogy. Physiology, is broadly biological, and this constant overlapping of closely related subjects is to be expected.

The study of the reactions of the protozoa to various stimuli has been much cultivated—both in zoölogy and in physiology—since these organisms exhibit life in relatively simple expressions. The illuminating quality of such experimental studies has been so fully recognized, that modern text-books on human physiology, in most cases, begin with an analysis of the properties of protoplasm and the physiological reactions of the protozoa. This is the best means of introduction to the study of experimental physiology.

*Animal Psychology and Animal Behavior.*—The divisions of animal psychology and animal behavior

may be considered as offshoots of general physiology. In recent years, these subjects have become much cultivated fields by zoölogists and psychologists. The results of these studies throw light on some of the basal problems of the development of animal intelligence and afford means of estimating the mental equipment of different animals. A few suggestive titles, taken at random, supply illustrations—*The Mental Powers of Spiders*, by the Peckhams, a widely-known study in comparative psychology; *The Behavior of Lower Organisms*, by H. S. Jennings; Romane's *Starfish, Sea-urchins and Echinoderms*, a study of physiological response; Chapters on the reactions of the Protozoa in the classical *General Physiology* of Max Verworn.

The mental evolution of animals is extremely interesting as affording illustrations, on another side, of that oneness of nature, the recognition of which as we have seen is one of the results of zoölogical study. Just as there are gradations of structure connecting the lower and the higher animals (the specialized arising by modifications from simpler ones) so, in the rise of animal intelligence, there is a graded series of states keeping pace with the structural differentiation of the nervous system.

Investigations in these fields have become so numerous that special periodicals have been established for the publication of researches of animal psychology and of animal behavior.

**Experimental Zoölogy.**—This is rather a method of broad application than a subdivision of zoölogy, and bearing this in mind, it forms a convenient caption under which to introduce several topics as Genetics, Mendelian Inheritance, Experimental Morphology, Experimental Embryology and Experimental Cytology.

*Genetics.*—Genetics, or the science of inheritance, has been the scene of great activity, has developed until it stands as a much pursued independent division of zoölogy. Experiments on the breeding of plants (corn, wheat, flowers, etc.) and animals have brought great extensions of knowledge regarding the growth and the conditions of inheritance in organisms.

*Mendelism.*—The whole subject of heredity has been pursued by experimental methods giving rise to a large number of special researches too numerous even to summarize. One feature that has occupied the center of the field is the study of Mendelian inheritance. This is properly a subdivision of

Genetics, but owing to the great prominence of the subject it is treated separately. Referring to Chapter IV for a statement of Mendel's law of alternative inheritance, we can say that it has been demonstrated in poultry, guinea pigs, rabbits and other animals. The fruit-fly which breeds rapidly and is easily kept under observation, has proved an excellent subject for observations of the effects of crossing and the study of unit characters. Morgan and his students have made extensive contributions to the study of heredity with this insect. They have added much to support the conclusion that the chromosomes are the normal mechanism for the transmission of Mendelian characteristics.

*Experimental Morphology.*—The earlier experiments of the last part of the nineteenth century were carried on under the name of experimental morphology—experiments on animals with a view to determine the changes undergone by changed conditions of life. Placing eggs and developing organisms under different conditions of environment and observing the results. The eggs and larvæ of aquatic forms are especially adapted for experiments of this nature—inasmuch as the chemical and thermal environment can be easily changed. The entire sur-

roundings can be materially changed by dissolving chemical salts not injurious to life in the water inhabited by these organisms. Observations with this kind of experimentation have been very helpful in attacking problems of the life of organisms.

Experiments on regeneration and conditions of growth have been numerous, and experiments on fertilization, both with sperms and with chemical salts, are among those which have yielded important results. In this connection should be mentioned the experiments of Loeb on artificial parthenogenesis and of Lillie on the nature of the fertilization process.

Wilhelm Roux, who has done very notable work in experimental morphology, has established a special periodical (*Archiv für Entwickelungs Mechanik*) for the researches in this field.

**Philosophical Zoölogy.**—The profound changes in thought produced by the establishment of the doctrine of organic evolution, and its effects upon our interpretations of nature, gave rise to the division of philosophical zoölogy. In this field are included the rise of evolutionary thought and the formulation of the different theories of organic evolution. The latter are attempts to designate the physical agency or agencies that have operated to bring about

organic evolution, the truth of which is so clearly evidenced by the facts of comparative anatomy, of embryology and of paleontology. Philosophical interpretations of development, of heredity, and of other zoölogical generalizations, also come under this division of zoölogy.

**Miscellaneous Divisions.**—Zoölogy has been broadened and enriched by the cultivation of especial lines of interest and this has led to an arbitrary subdivision of some of the larger provinces. The position of some of these subjects is not clearly defined and they owe their prominence to particular interest in their applications. Others of the miscellaneous group are clearly offshoots from the larger divisions.

*Eugenics.*—The subject of Eugenics (a subdivision of Genetics) commands at present a large place. This scientific study of the conditions that may improve or impair the racial qualities is properly undertaken only on a broad knowledge of biology and, especially, of zoölogy. As previously stated it was especially fostered by Francis Galton.

*Protozoölogy.*—In reference to unicellular organisms, a department of protozoölogy has been created with especial reference to pathogenic protozoa. But, quite outside the question of disease-producing

protozoa, it has long been recognized that in order to understand the real nature of living organisms one must first become acquainted with the phenomena of the Protozoa. The study of this single group has assumed so much prominence that, already there has been established in several universities a professorship of Protozoölogy.

The study of the life history of pathogenic protozoa, of parasitic worms and of other disease-producing and disease-carrying animal organisms has developed into a department of *Parasitology.*

The application of zoölogical facts to the benefit of mankind is a considerable feature of present-day work. This is a continuation and extension of the work inaugurated by Pasteur. Under this general head are included the demonstration of the connection between insects and the propagation of yellow fever, malaria, sleeping-sickness, typhoid fever and other disorders. Although still in their infancy much benefit has already accrued from zoölogical studies of this character.

*Economic Entomology.*—Investigations in economic entomology have become very active. They have been stimulated by the economic need of the control of the ravages by insect pests that have attacked

crops, fruit and shade trees. In response to this practical need, the researches on structure, habits, life history, development, conditions of life, etc., of insects have been greatly increased. A host of specially trained observers, widely distributed over the country, have produced important economic results which at the same time have greatly advanced zoölogical knowledge. The Bureau of Entomology at Washington has been the center promoting this kind of investigation and the results have been characterized by accuracy and scientific production of a high order. Some states and cities have well-organized departments for carrying on observations of this nature.

*Marine Zoölogy.*—The investigation of marine life has been greatly developed by exploring expeditions and by the establishment of seaside stations. The most famous of these is the international research station at Naples (*Stazione Zoölogica*) founded by Anton Dohrn in 1872. Tables and rooms for research in this station are maintained partly by the coöperation of universities and learned societies of the world. Researches carried on at the station are by no means confined to marine zoölogy, but the marine forms that are so abundant in the gulf of

Fig. 24.—Louis Agassiz (1807–1873)

Naples are used for the investigation of the widest range of zoölogical problems.

In the United States, Louis Agassiz (Fig. 24) was the pioneer with his marine station started in 1873 on the island of Penikese, Massachusetts. The Marine Biological station at Woods Hole, Massachusetts, is, in a sense, the successor of the Penikese laboratory. It was chiefly developed by Whitman (1842–1910) who had been a student under Agassiz. The influence of Whitman (Fig. 23) on the development of American zoölogy was very great. Besides acting as Director of the station at Woods Hole for nineteen years, he was a professor at Clark University and afterwards of the University of Chicago. He founded the *Journal of Morphology* and carried it through seventeen volumes. The greatness of Whitman was in his large noble spirit, his philosophical cast of mind and the feeling of uplift which he imparted to his students and to other zoölogists.

Other marine stations of the United States on the Atlantic Coast as Cold Spring Harbor, New York, South Harpswell, Maine, Dry Tortugas, Florida, and Beaufort, North Carolina, are supplemented by those of the Pacific Coast as the Puget Sound Station at Friday Harbor, Washington, Ocean Grove, Cal-

ifornia, La Jolla, California, and other places. In Great Britain the leading station is at Plymouth, while the marine stations of other European countries are numerous and important.

The explorations of the abysmal depths and the survey of the sea bottom have resulted in extension of zoölogical knowledge. These explorations of this character have been carried on by various government expeditions. The notable voyage of the Challenger (1872–1876), has led to the publication of monumental reports written by the coöperation of zoölogists of the different parts of the world. The recent Siboga expedition of Holland and the Harriman expedition of the United States brought much additional information about sea animals. To this class of voyages belong those on which Darwin (The Beagle) and Huxley (The Rattlesnake) made their trips as naturalists.

A department of oceanography has been created as a division, chiefly of zoölogy, and in deep sea investigations Sir John Murray of England and Alexander Agassiz of the United States made notable observations. Albert I., Prince of Monaco, maintains a station of oceanography on the French coast. This station is splendidly equipped, and important

contributions to knowledge have resulted from the investigations which are published in periodicals of the station.

*Limnology.*—Fresh water stations have been established at many points in the United States and in other countries in which the fauna of lakes and rivers have been scientifically studied. The pioneer station of this class was established by Zacharias at Plön, Holstein. Investigation of the biology of lakes and rivers is designated Limnology and work of this nature has assumed considerable importance.

In connection with aquatic observations, there has developed the plankton work, consisting of studies, both qualitative and quantitative, of the minute floating life of waters.

**Certain Recent Tendencies.**—The development of the experimental method and its wide application in the different departments of zoölogical investigation is the most characteristic recent tendency of zoölogy. Zoölogical investigation has successively advanced from the stage of mere observation to that of comparison and, finally, to the method of experimentation.

The greatest present activity is in some of the more recent offshoots of zoölogy such as: cytology,

the experimental study of heredity, including Mendelism, neurology, protozoölogy and parasitology, ecology, animal psychology and behavior, paleozoölogy and economic entomology. Morphological investigations on broad lines have been largely taken over by the anatomists, while the zoölogists are more engaged with cytology, ecology, genetics, etc.

In the line of cellular studies (cytology) there has been great refinement of technique and of observation. The minute constitution of the germinal elements and of the cellular phenomena of development have been worked out, the physical basis of heredity has been located in the chromosomes and, more recently, partly within the cytoplasm of the egg. These studies are closely allied with those of experimental embryology in which so many advances are being made—the nature of fertilization as a physiological process, etc.

The theory of sex-determination and the biology of twins have aspects of especial interest and, recently, have been investigated by zoölogists with important results.

In morphology, studies in neurology have taken the center of the field. Although there are many individual pieces of morphological investigation car-

ried out on a higher plane than that of previous years, investigations of the architecture of the nervous system in all its aspects is one of the obvious recent tendencies of zoölogy.

Coöperation in neurological research is a promising sign, made by the association of Neurological Institutes in a tacitly understood program of investigation. Some of the Institutes thus coöperating are those of Ludwig Edinger at Frankfort on the Main, of Ariëns Kappers of Holland and of the Wistar Institute of Philadelphia. In the United States the Wistar Institute of Anatomy and Biology is especially devoted to researches in Neurology under the leadership of Professor H. H. Donaldson.

**Adjuncts.**—Various adjuncts such as museums, zoölogical gardens, special collections, etc., have been helpful to the work of zoölogists. These have been of service in the dissemination of knowledge of animals among the masses, but, most of all, they have supplied facilities for the researches of specialists. Among the institutions of this type in the United States may be mentioned the Agassiz Museum of Comparative Zoölogy at Harvard University, the collections at Yale University, the American Museum of Natural History of New York City, the

Carnegie Museum at Pittsburgh, the collections of the Philadelphia Academy of Sciences, the National Museum and the Smithsonian Institution at Washington.

Zoölogical gardens exist in New York, Washington, Philadelphia, Chicago and at other places.

The embryological collection of the late Dr. Charles Sedgwick Minot of Boston and of Dr. Franklin P. Mall (died 1917) of Baltimore are of great service to investigators in embryology.

The entomological bureau at Washington, D. C., and several of the State Entomologists have done much to advance and to spread broadcast the knowledge of Insects. The sumptuous publications of the United States government have placed in hand many valuable reports on animal life and animal industry. The activities and publications of the United States Fish Commission are also notable.

## CHAPTER XII

## A CHAPTER ON INSECTS

INSECTS are so interrelated with general topics that a chapter on insects will serve to further illustrate the progress of zoölogical study.

This is the largest group of animals, there being approximately 400,000 species described and classified and there are many not named. From whatever point of view these animals have been studied, they have awakened interest and enthusiasm among naturalists. Those who devote particular attention to this field of study are designated entomologists and the great division of zoölogy thus set apart is designated entomology.

From the time of Malpighi (1628–1694) and Swammerdam (1637–1680) insects have been objects of interest and of especial consideration to the minute anatomists.

In their life histories some insects, as the butterflies, bees, etc., exhibit in the clearest fashion and in the widest range the phenomena of metamorphosis. Hatching from the egg in a form different from the adult many of these animals pass through various

stages of moults as larvæ, then enter the quiescent or pupa stage and emerge from the cocoons, or cases, as adults.

In reference to the fertilization of flowers insects exhibit some of the most interesting relations of nature. With remarkable adroitness they extract the nectar of flowers, and at the same time carry pollen from flower to flower, and further cross-fertilization. Often there are especial adaptations in structure to promote this end.

But it is in reference to their habits that they show the most extraordinary display of instinctive intelligence and complex behavior. Those forms as ants, bees and social wasps living in social communities, that are well organized as to divisions of labor and concerted action, may be properly regarded as animals of dominant intelligence.

The French entomologist J. H. Fabre (1823–1913) devoted a long life to observation of insects showing especial aptitude for searching out their habits. He has related his observations in voluminous and charming writings which reached the dimensions of ten volumes under the title of *Souvenirs Entomologiques*. These memoirs have been translated into English and have had a wide circulation. Fabre

(Fig. 25), on account of his talents as an observer, his gifts as a writer and his direct appeal to a non-technical audience is probably more widely known than any other entomologist. Those who wish to taste the flavors of this charming writer on natural history are recommended to look into his volume on *The Hunter-Wasps.*

Other entomologists, more important from the scientific standpoint and who have addressed only a scientific audience are less generally known.

Obviously it would be out of keeping to attempt in a few pages to treat of the various aspects of the large and complex group of insects. Accordingly, only a few selected topics will be brought briefly under consideration.

On account of their relation to the transmission of diseases insects have become of world-wide interest, and those topics are selected that best illustrate their connection with human diseases. These are Malaria, Yellow Fever and Sleeping-sickness. It is to be borne in mind that there are other human diseases transmitted through the agency of insects, as bubonic plague, sometimes, typhoid fever, etc., and many animal diseases of cattle, horses and lower animals.

**Malaria.**—Let us become acquainted with the

circumstances under which was demonstrated the transmission by insects of Malaria. Malaria is a widely-spread infectious disease. This disease, characterized by periodically recurring chills and fever was called Malaria, which means bad air, from the belief that the Malaria was due to miasmatic vapors arising from swamps and marshes. The disease, formerly called fever and ague, was observed to be most prevalent in marshy districts and in places with standing water. It is now known that this is owing to the fact that wet places supply the conditions for the nurture of the mosquitoes that transmit the disease.

That it is transmitted by a particular kind of mosquito was well established by Ross in 1898. There were several steps leading up to this final demonstration each one of which is an interesting bit of biological advance.

It was in 1880 that Laveran, a French military surgeon, then serving in Algeria, made known the presence of a micro-organism within the blood of patients suffering from malaria. This so-called plasmodium is a microscopic animal (protozoan) parasite. In the blood of an infected person the minute malarial parasite bores its way into a red blood corpuscle and feeds and grows at the expense

of the protoplasm of the corpuscle. It rapidly grows and divides into a progeny of thirteen to eighteen small spore-like individuals which are set free into the blood by the bursting of the wall of the blood corpuscle. This sporulation occurs periodically and corresponds to the attacks of chills followed by fever, which attacks are intermittent, depending on the life cycle of the parasite.

There are two varieties liberated into the blood stream, those in largest number being able to multiply by direct division, while the other kind consist of germinal elements that require a different host and a different set of conditions in order to unite and complete their life history. Their union is a process of fertilization and is accomplished in the blood of a mosquito, in which animal they undergo a complicated development, resulting finally, in an immense number of spore-like individuals.

The history of the first kind is more simple. They bore their way into new corpuscles and repeat the changes mentioned above. The number of corpuscles infested is continually multiplying so that soon the blood becomes the seat of a prodigious number of the malarial parasites.

The rate at which they are produced varies with

different species. If they mature and produce spores in thirty-six hours, the patient has chills and fever every other day—for the chills and fever correspond to the period of sporulation and bursting of the corpuscles. There are other species with a different period of growth giving rise to the different types of malaria—the three-day, the four-day, etc. Minute as they are these different varieties can be distinguished under the microscope.

The question of how the parasite gets into the blood had now to be solved as a step in tracing the infection to its source. Suspicion was fastened on the mosquito and after observations by several investigators it was finally shown in 1898 that the bite of a particular species of spot-winged mosquito transmits Malaria. (Grassi had previously shown that these parasites complete a part of their life history in the body of the mosquito.) The scientific name of the mosquito is Anopheles. The Culex or common house mosquito is not a malaria carrier. The Anopheles is widely distributed. It is a night-flier, and only the female circulates, sucks blood, and, when infected, transmits the disease.

In the most infected districts it was experimentally demonstrated that to remain in well-screened

shelters after sundown was sufficient to protect against infection. Experiments on a large scale were also carried on in the most infected districts of the swampy campana of central Italy. Camps were constructed in these unhealthy districts and the persons experimented upon were divided into two groups that lived under similar conditions—except that one group was protected in well-screened rooms, though freely exposed to the fogs and vapors from the marshes. The other group was unprotected by screens. The results were spectacular. Those protected from the bites of mosquitoes contracted no fever while those that were exposed to mosquito bites were stricken with malaria.

As a further experiment infected mosquitoes were sent from Rome to London and there allowed to bite healthy person who were by this means infected with malaria fever. Thus was forged the last link in the chain of evidence connecting the Anopheles mosquito with the transmission of malarial fever.

This was the first demonstration of direct connection between insects and the transmission of a specific disease. Although suggestions that insects act as disease carriers are found scattered through scientific literature for a number of years, neverthe-

less, experimental evidence proving the truth of the theory was lacking. Dr. Manson (later Sir Patrick) in 1880 was the first to show that the blood of human beings may become infected with a worm-like parasite (*Filaria sanguinis*) by the bites of a mosquito. Others as Dr. A. F. A. King (1883) contended on theoretical grounds that mosquitoes carry malaria but adduced no experimental evidence. It was in 1894 that Manson communicated his theory concerning mosquitoes to Major Donald Ross of the British army and on this suggestion he began working on malaria in India. For more than two years his results were negative because he worked on the mosquito Culex—but, turning his attention to Anopheles, he was soon able to trace in this form part of the life cycle of the malaria parasite. Many observers had a part in bringing the demonstration to a conclusion. Grassi, the Italian, did important work (1894), but Ross, with the assistance of suggestions from the work of others, and utilizing their partial results, was able to demonstrate so completely that the malarial parasite is transmitted to human beings through the bite of a particular kind of mosquito, that credit for this great discovery is usually accorded to him.

His observations afford a typical example of the method of zoölogical research—a combination of observation, of experiment and of discerning deduction derived from the results of the complex and involved relations. Several steps were necessary to reach the final conclusion:

1. The discovery of the micro-organism in man by Laveran in 1880.

2. Tracing the life history of this germ showing that only a part of its life cycle is carried on in the human body and that another part is in the body of the Anopheles mosquito.

3. Demonstrating that the bites of an infected Anopheles mosquito transmits the disease.

4. Camp experiments showing that it is not due to other causes.

Malaria cannot be contracted by contact with an infected patient, nor through the inhalation of vapors of swamps. The question now arises, how does a mosquito become infected? When a mosquito sucks blood from a person suffering from malarial fever it draws into its body blood containing the parasite (the second variety mentioned that reproduce by fertilization) some of which are in a condition to conjugate. These forms conjugate and

undergo a development in the walls of the stomach of the mosquito. The conjugation is a sort of fertilization such as occurs in all animals and plants, but it will not take place in human blood. A "secondary host" is necessary in which to complete the life cycle. After fertilization the developing forms produce nodules on the walls of the stomach of the mosquito and in these nodules takes place the transformation into spindle-shaped forms which get into the salivary ducts of the mosquito. When biting, the mosquito injects some of these into the blood of the victim and there they begin to multiply rapidly by asexual budding.

Doses of quinine are used to kill the malarial parasite.

Studies of the development of the mosquito soon led to methods of protection. Mosquitoes breed in water—a small quantity being sufficient. Protection comes from draining marshes, getting rid of pools and of containers of exposed water, and from spraying with crude petroleum so that the wigglers which hatch from the eggs can not get air, and consequently, the mosquito can not come to its full development. The use of screens and remaining indoors after sundown are also wise measures of precaution.

These methods have cleared malarial regions of the sources of infection and, in particular, in the Panama zone, conditions were established that made possible the construction of the Panama Canal.

**Yellow Fever.**—There is no more interesting and inspiring chapter of biological achievements than that of the struggle and the triumph of demonstrating the nature and the means of conveyance of yellow fever. This is one of the greatest medical discoveries of any century. It is usually designated the greatest American medical discovery—but, it stands in parity with another medical advance originating in the United States, viz., painless surgery, accomplished by means of the administration of ether.

Yellow fever is a rapidly spreading, most dreaded and very fatal disease of tropical and sub-tropical climates. Havana and Gulf ports have repeatedly been the scene of this great scourge. Up to 1898 it was believed to be communicated by infected articles of clothing, bedding, furniture, etc., and, further, that it was commonly introduced into the body through respiration. But, thanks to the investigations of Walter Reed and his associates, it is now thoroughly demonstrated that yellow fever is transmitted through the bite of a mosquito and in no

other way. Just as malaria is always transmitted by mosquitoes of the Anopheles variety so also is yellow fever carried by another mosquito of the genus Stegomyia.

In the year 1900, President McKinley appointed Dr. Walter Reed (Fig. 26) as chairman of a committee to proceed to Havana for the study of infectious diseases—more especially yellow fever. In about six months after his arrival he, with the assistance of his associates, had shown that yellow fever is transmitted only by the bite of a particular kind of mosquito.

Some of his results summarized are as follows:

1. The virus or germ exists for the first three days in the blood of the sick before it is capable of producing infection.

2. A mosquito of a single species—Stegomyia fasciata—becomes infected by sucking blood from a sick person, and after twelve days have elapsed (and thereafter) can carry the disease.

3. There is no other way of infection.

Reed's work is another illustration of the power of applied intelligence guided by scientific observation.

The essential steps involved in this discovery are similar to those in the investigation of malaria:

FIG. 25.—J. HENRI FABRE
(1823–1913)

FIG. 26.—WALTER REED (1851–1902)
From H. A. Kelly's *Walter Reed and Yellow Fever*

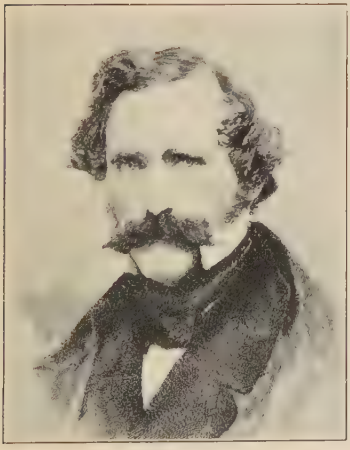

FIG. 27.—W. T. G. MORTON (1819–1868)
From Camac's *Epoch-Making Contributions to Medicine*

FIG. 28. EDWARD JENNER
(1749–1823)

1. The particular organism producing the disease is not known—probably because it is too small for microscopic observation. Nevertheless, it is demonstrated that there is something in the blood that produces the disease. This something is assumed to be of animal nature—owing to the requirement of two hosts and a relatively long time to complete its cycle. For want of a better name it is designated a virus.

2. The demonstration that it can not be transmitted by clothing, bedding, contact with the sick nor through the atmosphere. Prior to 1898 it was generally believed that these were sources of infection but two young privates of the United States army—John R. Kissinger and J. J. Moran—volunteered to put the question to a practical test, and for twenty nights they slept in contact with bedding and night clothing removed from those sick and dying with yellow fever. No contagion followed and thus it was proved that the disease can not be conveyed in this manner. This service to the cause of science by these two men involved great courage and high devotion to the cause of humanity.

3. Experimental evidence that, on the other hand, yellow fever is transmitted by the bite of

the mosquito Stegomyia. John Moran of the United States army submitted to the bite of an infected mosquito—as a result he was stricken with the disease but recovered. Dr. Lazear, one of Reed's assistants, was accidentally bitten by a mosquito and died of yellow fever. The circumstances attending both these cases were such that no doubt existed as to the direct connection between the bite of the infected mosquitoes and the disease.

Reed appreciated the significance of his discovery, and in the first enthusiasm of the demonstration he wrote this intimate estimate to his wife: "Rejoice with me, sweetheart, as aside from the antitoxin of diphtheria and Koch's discovery of the tubercule bacillus, it will be regarded as the most important piece of work, scientifically, during the nineteenth century."

The results of the demonstration were immediate and far reaching. Havana and Gulf ports were practically freed from the disease. Indeed, since 1901, Havana, formerly the favorite home of this deadly disease, has been exempt from its ravages.

**Sleeping Sickness.**—The third of these biological studies of insects and transmission of diseases involves the sleeping sickness. The sleeping sickness

is a strange mysterious disease characterized, as the disease progresses, by lethargy and a somnolescence which terminates fatally.

It had long been known on the western coast of Africa, but, in 1901 a virulent outbreak occurred in central Africa, in the Uganda district and along the shores of Lake Victoria Nyanza. The disease killed so many that the British government undertook to investigate the causes of the disease and to seek a remedy. The wide-spread nature of this epidemic in which 200,000 died in one year compelled notice. Colonel Bruce of the British navy, who was experienced in the investigation of infectious diseases, was sent there in 1903 to investigate the conditions and the characteristics of the disease.

As in the case of malaria and yellow fever it took the highest qualities of scientific observation to discover the particular organism of the disease and to find out the way in which it is transmitted. Colonel Bruce had the problem to work out, of the nature and the mode of infection of sleeping sickness. He determined that as to its nature, it is produced by the presence in the blood and the cerebro-spinal fluid of a cork-screw shaped parasite—a minute animal organism somewhat longer than the diameter

of a blood corpuscle. This organism is sharp pointed at each end and is provided with a vibratile membrane and a flagellum which produce motion. This parasite—called a trypanosome—was, by Bruce and other observers, found in the blood and spinal fluid as a constant concommitant of the disease.

Its mode of transmission was obscure and a problem of great difficulty. Studies on the wild and domesticated animals of the district were a means of throwing light on the matter. Similar protozoan parasites were known to infect domesticated animals and to live in the blood of native wild animals such as the antelope, buffalo, and others. These wild animals having been long infested with these parasites had acquired a tolerance for them and remained unharmed, but recently infected domesticated animals were not immune. These parasites were shown to be conveyed by the bite of a tsetse-fly from the wild game inhabiting the district—in whose blood they produce no deleterious result—to the animals that were susceptible to poisons produced by the parasites. By analogy, suspicion was fastened on the tsetse-fly as the probable source of transmission, but it was a very difficult matter to prove it. In searching for the agent of the transmission of human

sleeping sickness, Bruce had the help of many native collectors who were paid to bring to his camp the various flies and other insects of the district. Finally, the source of transmission was fastened on a particular species of the tsetse-fly—Glossina palpalis. The tsetse-flies are a genus of flies only found in Africa. There are seven species known—the particular fly that transmits sleeping sickness in human beings is a little bigger than the common house fly and much like it in color.

To establish an undoubted connection between the tsetse-fly and the transmission of sleeping sickness came to Bruce as a triumph of scientific observation and deduction. Finding that monkeys also were susceptible to the disease he caused infected flies to bite monkeys, thus producing the disease and demonstrating the mode of its transmission.

In 1906, a sort of arsenic aniline (Atoxyl) was found by Thomas and Breinl to be helpful in some cases. The suggestion of this substance as a possible remedy was erroneously ascribed to Robert Koch who merely confirmed the observations of the earlier investigators.

To avoid a common confusion it may be well at this point to emphasize the fact that the three

diseases spoken of above are all produced by animal organisms. On the other hand, the bacteria whose pathogenic qualities have been known so long are plants. Thus, typhoid fever, tuberculosis, diphtheria, etc., are produced by plant parasites and malaria, sleeping sickness, and probably yellow fever are produced by minute animal organisms.

Among other diseases transmitted by insects may be mentioned the bubonic plague, by the bite of lice of rats; many diseases of cattle, by bites of flies, ticks, etc. These insects pass along the disease germs which they have derived by blood sucking from other animals.

## CHAPTER XIII

## THEORIES OF EVOLUTION

THE circumstances surrounding the rise of evolution theories in the nineteenth century are not generally understood. There is a wide-spread belief that the theory of Charles Darwin was first in the field, and, confusion on this point is so general that whenever organic evolution is mentioned many people conclude that the particular hypothesis of Darwin is always referred to, but such is by no means the case. By organic evolution is meant the great natural process through which animals and plants have come to be what they are—a purely historical question of what has happened in the past to produce the transmutation of animals and plants—in a word, the discovery of the lineage of living organisms. Darwinism, on the other hand, is one explanation offered to account for the evolution of animals and plants. Darwin undertakes to designate the particular agency that has been at work in nature to produce the various kinds of organisms. Darwinism refers specifically to the action of natural selection as the chief agent in bringing about organic evolution.

To Lamarck, the eminent French zoölogist, belongs recognition as the founder of the doctrine of organic evolution, fifty years before the publication of Darwin's great book, *The Origin of Species*. It is true, however, that the publication of Darwin's book was the means that brought the matter prominently before the world and started the vigorous controversy regarding the truth or falsity of the theory.

There are four theories of organic evolution that have received a large amount of attention from naturalists in addition to several supporting and some rival theories. No one can be adequately informed on the matter who does not take the trouble to get an idea of the prominent features of these theories and their relation to one another. The four theories referred to are those of Lamarck, Darwin, Weismann, and De Vries.

**Lamarck.**—Although the evolutionary point of view had been vaguely suggested at different times prior to Lamarck, he was the first to announce a comprehensive theory of organic evolution that has maintained to the present time a creditable standing in the intellectual world. His immediate predecessors, Buffon, Goethe, and Erasmus Darwin (grandfather of Charles Darwin), dealt with the same great

theme but much less rigorously than Lamarck. The earlier theories were either too vague and discursive or too inadequate to serve as foundations. Lamarck's theory was so much more thoroughly thought out that it completely superseded all earlier attempts and marks the beginning of evolutionary thought in its modern sense.

Lamarck (Fig. 29) first gave expression to his evolutionary ideas in 1800, in an introductory lecture to a course of instruction regarding the invertebrates. This was published in 1801. The theory was somewhat elaborated in the years 1802, 1803, and 1806. Finally, it was fully expounded in *Philosophie Zoölogique*, in 1809, and that year marks the first distinct epoch in the rise of evolutionary thought.

In this book he sets forth the basis of his conclusions. He ascribes to the effects of use and disuse the various modifications of organic structures—use tending to increase, and disuse to decrease the size and efficiency of organs. The changes thus produced, by organisms adapting themselves to the conditions under which they live, were supposed by Lamarck to be directly inherited and improved (or further decreased) in succeeding generations.

It appears, he says: "that time and favorable con-

ditions are the two principal means which nature has employed in giving existence to all her productions." When surrounding conditions are stable the evolutionary process reaches a stage of equilibrium, but, when the environment varies (or new needs arise), the new conditions of life impress themselves on the plastic organisms and they become altered to better adapt themselves to these new conditions. His theory as set forth was comprehensive and included the evolution of the human body as well as all other organisms.

Adaptation of organisms to environment, in general and in detail, producing changes of structure through use and disuse of organs and the direct inheritance of the modifications is a simplified statement of Lamarck's theory.

Until Lamarck was fifty years of age he was a botanist and had secured a lasting reputation in that field, but, in 1894, when the *Jardin des Plantes* was reorganized he was appointed to a position in Zoölogy in charge of the invertebrates. Apparently, it was the observations he made in connection with these new duties that led to the formulation of his theory. At this time the belief was current that species are unalterable. The dogma of the fixity of species

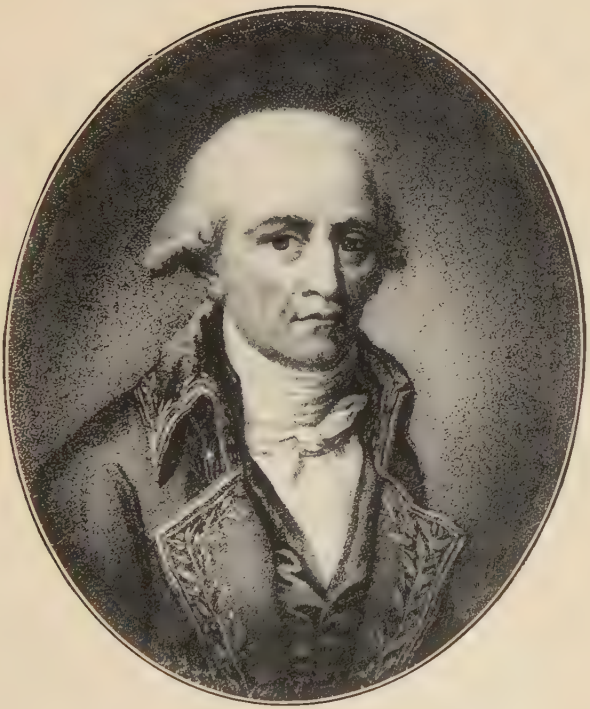

FIG. 29.—J. B. LAMARCK (1744–1829)
From Thornton's *British Plants*, 1805

prevailed. Linnæus had announced himself in favor of the idea, and, so generally was his authority recognized, that scarcely anyone thought of bringing it into question. But Lamarck saw that species vary in a state of nature to such an extent that they pass beyond the limits that can, in reason, be assigned to species.

Lamarck's theory, although so definite, did not find a foothold during his lifetime and the fifty years between 1809, when his book was published, and 1859, when Darwin's *Origin of Species* appeared, was characterized by the temporary disappearance of the theory of organic evolution. His ideas were ridiculed by Cuvier and were practically laughed out of court. Charles Darwin also paid little heed to Lamarck as a predecessor. But, it is a significant circumstance that, nearly a century after being promulgated, Lamarck's principle of use-inheritance and the beginning of variations should have been revived, and, under the title of Neo-Lamarckism, should occupy such a prominent place in the discussions regarding the factors of organic evolution that are being carried on at the present time. The revival of Lamarckism is especially owing to the paleontological investigations of Cope, Hyatt and

others. The work of E. D. Cope, in particular, led him to attach importance to the effects of mechanical and other external causes in producing variations in animal structure, and he has pointed out many instances of use-inheritance.

Lamarck's theory was founded on two sets of facts—those of variation and heredity. These are essential to any theory of transmutation of species. Lamarck undertook to account for variation through the influence of environment during the lifetime of the individual, and the direct inheritance of these purposeful variations was assumed. This is the inheritance of acquired characters which as we shall see was vigorously opposed by Weismann.

**Darwin.**—Darwin's theory is based on three sets of facts—variation, heredity, and natural selection. Two of the factors are the same as those of Lamarck but they were treated differently by Darwin. Lamarck undertook to assign causes for variation. Darwin (Fig. 5) accepted variation and assumed that there is continually occurring in living organisms many small fluctuations in structures. Naturally many of these small, fortuitous, variations would be swamped, but, obviously, some of them are retained and improved upon. His reply to the ques-

tion: "What particular variations will be perpetuated?" was, "only those that prove of benefit to the race in the struggle for existence and in adapting themselves to environment." The chance inheritance of the multitudinous variations would produce chaotic results unless directed by some agency and this directing agency was designated by Darwin, Natural Selection. This is the central idea of Darwin's theory and the essentially new factor that he added to the discussion. He observed the changes produced by artificial selection under domestication of animals and cultivation of plants. Certain variations are selected by breeders and agriculturalists to be bred intensively, and, by this means, marked changes are produced in pigeons, poultry, dogs, cattle, flowers, etc. Now since these changes are obviously the result of a process of selection on the part of man, Darwin concluded that conditions exist in nature which lead to the selection of certain variations to survive and to the suppression of others.

Some such assumption is necessary, because there is a tendency to overproduction in animals and plants, leading to a struggle for existence, and, the determination of survival, would scarcely be a matter of chance. One illustration will suffice to carry the

idea. A single trout, for illustration, lays from 60,000 to 100,000 eggs. If the majority of these arrived at maturity and gave rise to progeny, the next generation would present a prodigious number, and the numbers in succeeding generations would increase so rapidly, that soon there would not be room in the fresh waters of the earth to contain their descendants. It is true that most animals produce fewer eggs (some lay more), but observation establishes the truth that animals tend to multiply by geometric progression, while as a matter of fact the number of any one kind remain practically constant.

The agency that determines which organisms shall be preserved in the struggle for existence is natural selection. This agency will favor certain variations in structure that may prove of advantage, so that, in the long run, those best adapted to conditions of life would survive.

Natural selection works in such a variety of ways that a few illustrations are essential. Fleetness in such animals as antelopes may be the particular thing which secures their safety. In all kinds of strain due to scarcity of food, inclemency of weather and other rigorous conditions, those forms with the best powers and physiological resistance will have

the best chance to survive. The keen vision of birds of prey, such as hawks, will be a factor in their preservation. Those hawks that are born with weak or defective vision cannot cope with the conditions under which they get their food. Natural selection compels the eye to come up to a certain standard and the conditions of living maintains the standard. Certain animals are protected from their enemies by being inconspicuous—conforming to the colors of the background on which they live—resembling twigs and other natural objects. In other cases, especially among insects, flaming colors give warning that the animals are of noxious taste and their pursuers learn to leave them alone. An illuminating instance of the action of natural selection is the production of weak-winged beetles from strong-winged ancestors. In very windy islands the strong-winged forms being more in the air and flying further from protection are blown out to sea. The weak-winged are better adapted to these particular conditions, and, natural circumstances tend to favor them and to operate against the strong-winged individuals. This makes one point clear—natural selection tends to adapt animals to their conditions of life and results, not always, in the survival of the

best, that is the ideally perfect, but in the survival of the fittest. A similar instance is found in the suppression of certain sets of organs in internal parasites. The organs of digestion, not being necessary under their condition of life, are suppressed, but the reproductive organs, upon which continuance of the race depends, are greatly increased. These illustrations will assist in giving an idea of what Darwin meant by natural selection.

One other point should be emphasized. Darwin, who was one of the most candid, sincere and straightforward of men, did not claim that natural selection was the only natural agency but merely the chief one in bringing about evolution.

Darwin's theory met with a very different reception from Lamarck's. It received immediate attention. It was vigorously attacked and defended and was ultimately accepted. The contrast was so great that naturally the inquiry arises—Why? It was promulgated more than fifty years after Lamarck's announcement and, in the meantime, the way had been prepared by the publication of Lyell's *Principles of Geology* (1830), by Chambers' *Vestiges of Creation* (1844), by Herbert Spencer's writings regarding the reasonableness of the hypothesis of

development (1852) and by other writers. The times were more favorable for launching the great idea of evolution. But the wide currency which the idea immediately attained was chiefly owing to Darwin's exposition of the idea of natural selection. He designated explicitly a natural cause for the changes in animals that had heretofore been so perplexing. Even the masses could understand his argument. The character of his first publication (*Origin of Species*, 1859) was also such as to attract attention and secure respect. He had been at work on his theory, experimenting and observing, for more than twenty years, and his publication showed that quality of thoroughness, fairness and ripeness that commanded consideration.

Among those who assisted in the spread of the Darwinian theory amongst English-speaking people, Thomas Henry Huxley (Fig. 31) stood preëminent. Darwin was of pacific disposition while Huxley was aggressive and both ready and forceful in public debate. He became the recognized champion of the theory of descent, and vigorously and effectively defended it against attack.

It is an interesting circumstance that Alfred Russell Wallace (1823–1913), by a flash of insight, had

arrived independently at the idea of struggle in nature, with the survival of the fittest through natural selection. He communicated these ideas to Mr. Darwin in 1858, and, with high-minded generosity, Darwin was disposed to allow the credit to go to Mr. Wallace, withholding his own publication upon which he had been working for so many years. He was pursuaded to leave the matter in the hands of two of his friends, Sir Charles Lyell and Joseph Hooker, who arranged for the publication simultaneously, of manuscript sketches of Darwin, made in 1839, 1844 and 1857, and the essay of Wallace prepared in 1858. Although Darwin was so punctilious about having his friend, Wallace, receive a share of the credit, Wallace himself has insisted, and the world has recognized, that the credit for the natural selection theory belongs essentially to Darwin.

**Weismann.**—The theory of Weismann is more complex and is difficult to state with brevity and lucidity. It will dispel a wide-spread confusion regarding his theory to say, at once, that he is a Darwinian—the recognized leader of the Neo-Darwinians. He carried the idea of natural selection further than Darwin did, extending it to the tissues and even to the minute vital elements of the cell. It

is to be understood, therefore, that as regards Darwinism, his is a supplementary or supporting theory and not a replacing theory.

It is complex and involves assumptions as to the behavior of a number of hypothetical vital units, designated by Weismann: idants (chromosomes); ids (chromomeres), determinants, and biophors (the elementary vital units). Two of these, the ids and the idants are visible under the microscope, but the determinants and the biophors are too minute to be rendered visible.

His theory of evolution is in reality the outcome of his theory of heredity, designated the "Continuity of germ-plasm," and to comprehend his reasoning it is necessary to understand what is meant by the germ-plasm and by its continuity.

As is well known, animals and plants arise from germinal elements of microscopic size; these are, in plants, the spores, the ovules and their fertilizing agents; and, in animals, the eggs and the sperms. Now, since all animals, even the highest, begin their existence as a fertilized egg, that structure, minute as it is, must contain all hereditary qualities, because this is the only material substance that passes from one generation to another. This formative sub-

stance is the germ-plasm. It is the living vital substance of organisms that takes part in the development of new generations.

Weismann (Fig. 32) points out that the many-celled body was gradually produced by evolution, and that in the transmission of life by the higher animals the continuity is not between body-cells and their like, but only between germinal elements, around which in due course new body-cells are developed. Thus he regards the body-cells as constituting a sort of vehicle within which the germ-cells are carried. The germinal elements contain the primordial substance around which the body-cells have developed, and, since in all the long process of evolution the germinal elements have been the only form of connection between different generations, the substance composing them has unbroken continuity.

This conception of the continuity of the germ-plasm is the foundation of Weismann's doctrine. It is one of the most fruitful biological ideas developed during the nineteenth century, and it replaced as a basis all earlier theories of heredity. Although Weismann was not the originator of the idea of germinal continuity, he is nevertheless the one who has developed it the most extensively.

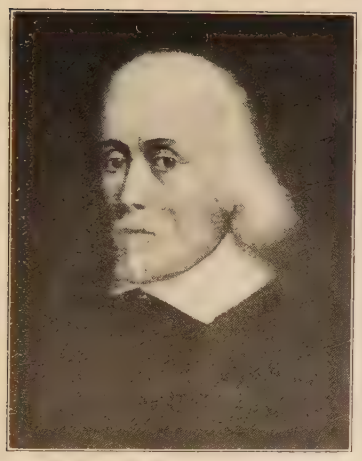

FIG. 30.—WILLIAM HARVEY
(1578–1657)

FIG. 31.—THOMAS H. HUXLEY
(1825–1895)

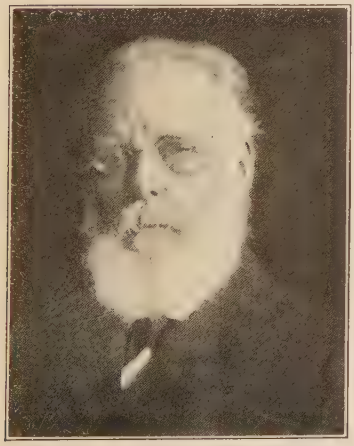

FIG. 32.—AUGUST WEISMANN
(1834–1914)

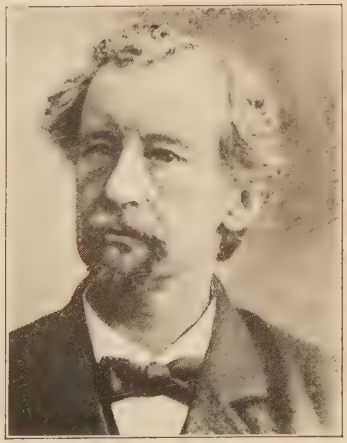

FIG. 33.—HUGO DE VRIES

In 1893 there was published an English translation of his famous book *The Germ-Plasm* which stimulated so much discussion among biologists. This sets forth his theory of heredity. For many years Weismann was a professor in the University of Freiburg, and his lectures on the evolution theory were deservedly famous and well attended. The best exposition in English of his theory is *The Evolution Theory*, published in two volumes in 1904. In the preface he says: "I make this attempt to sum up and present as a harmonious whole the theories which for forty years I have been gradually building up on the basis of the legacy of the great workers of the past, and on the results of my own investigations and those of my fellow-workers."

Since we may assume that there has been unbroken continuity of the germ-plasm from the beginning, we may also assume that its organization has become very complex. Protoplasm is impressionable, responding to various forms of stimuli and undergoing modifications in response to environmental influences. These subtle changes occurring within the protoplasm affects its organization, and, in the long run, it is the summation of experience that determines what a particular mass of protoplasm shall be and

how it will behave in development. Two separate masses of protoplasm differ in detail, as to capabilities and potentialities, according to the experiences through which they have passed, and no two will be absolutely identical.

We have seen that variation and heredity are the two primary factors of evolution. The way in which Weismann accounts for variation among the higher animals is both ingenious and interesting. In all higher organisms the sexes are separate and reproduction of their kind involves the union of germinal elements from both parents.

As previously stated, the germinal elements involved are ovules and pollen of plants and eggs and sperms of animals. In animals, the egg bears all hereditary qualities from the maternal side, and the sperm those from the paternal side. The intimate mixture of these in fertilization gives great possibilities of variations arising from the different combinations and permutations of the vital units within the germ-plasm.

The variations once started will be fostered by natural selection.

It is now evident that if we follow Weismann's conclusions logically, there can be no inheritance of

acquired characters—that is, of acquisition made by the body-cells, or changes arising in them, during the lifetime of the individual. None of the body-cells are transmitted and the hereditary qualities must all be located within the plasms of the germ-cells.

The outstanding features of Weismann's theory are as follows:

1. The germ-plasm has unbroken continuity from the beginning of life.

2. Heredity is accounted for on the principle that the offspring is composed of some of the same stuff (germ-plasm) as its parents. The body-cells are not inherited.

3. Consequently, there is no inheritance of acquired characters.

4. Variations arise from the union of the germinal elements, giving rise to varied combinations and permutations of qualities of the uniting germ-plasms.

5. Weismann adopts and extends the principle of natural selection.

**De Vries.**—Hugo de Vries (Fig. 33), director of the Botanical Garden in Amsterdam, has experimented widely with plants, especially the evening primrose (*Œnothera Lamarckiana*), and has shown that different species appear to rise suddenly. These

sudden variations that breed true, and thus give rise to new forms, he calls mutations. This indicates the source of the name applied to his theory.

In his *Die Mutationstheorie*, published in 1901, he argues for the recognition of mutations as the universal source of the variations that lead to species-formation. Although he evokes natural selection for the perpetuation and improvement of variations, and points out that his theory is not antagonistic to that of natural selection, it is nevertheless directly at variance with Darwin's fundamental conception, that slight individual variations "are probably the sole differences which are effective in the production of new species" and that "as natural selection acts solely by accumulating slight, successive, favorable variations, it can produce no great or sudden modifications."

The work of De Vries is a most important contribution to the study of the origin of species, and is indicative of the fact that many factors must be taken into consideration when one attempts to analyze the process of organic evolution. His observations widen the field of exploration. While he has demonstrated that species may arise by mutations, there is at the same time good evidence—from

paleontology and other sources—that species may also arise by slow accumulations of small variations.

One great value of his work is that it is based on experiments and that it has given a great stimulus to experimental studies. Experiment was likewise a feature of Darwin's work, but that seems to have been almost overlooked in the discussions aroused by his conclusions. De Vries, by building upon experimental evidence, has led naturalists to realize that the method of evolution is not a subject for argumentative discussion, but for experimental investigation.

**Other Theories.**—In addition to the four theories briefly outlined other theories have been advanced, which, in their relation to the Darwinian hypothesis of natural selection, fall into two categories. There are competing theories designed to replace that of natural selection, and there are auxiliary, or supporting theories, that are designed to throw new light on the conditions of species-forming, and to strengthen the natural selection theory by its more complete elucidation. Such an extensive literature has grown up in the discussion of these matters, that even summaries would unduly prolong the subject of this chapter. The entire case has been presented with

remarkable clearness in Kellogg's *Darwinism To-day*, to which volume the reader is referred for fuller information.

There are, however, two ideas of fundamental importance in post-Darwinian discussions that should receive mention. These are designated respectively, orthogenesis and isolation. Theodor Eimer, since 1888, has been the typical representative of the ideas of orthogenesis—which means development in a straight or definite direction. He maintains that variations of organisms take place, not fortuitously in radiating lines, but follow a few definite directions. He insists that variations are not preserved on the basis of their utility, but as the result of the direct inheritance of acquired characters. This is intended as a replacing theory for that of natural selection.

Isolation as a favoring condition of species-formation has been championed by Moritz Wagner (since 1868) and, more recently, by David Starr Jordan, Gulick, Romanes and others. This is based on the obvious fact that slight variations will be more likely to persist if the species in which they occur are segregated, or isolated, so that those exhibiting similar variations shall be compelled to

breed together. Slight variations before they become fixed are very unstable, and they would very likely disappear if the breeding were general with species exhibiting counter variations. Isolation of species, by geographical barriers or other natural circumstances, would lead to interbreeding and favor the perpetuation and improvement of small variations. After the variations are started and lifted to a plane where natural selection can take hold, then the latter agent would become operative. Natural selection originates nothing but guides the course of evolution after variations are sufficiently developed to make a difference in the struggle for existence.

Before closing this chapter a word regarding the present status of the doctrine of organic evolution will be in order. With so many discussions in scientific circles regarding aspects of evolution there is little wonder that the general public should be confused, and that reports are often circulated that there is a tendency on the part of the scientific world to recede from the doctrine or even, to surrender it. This vagueness regarding the present status of the theory of organic evolution arises chiefly from not understanding the nature of the points at issue. Never before was the doctrine of organic evolution so

thoroughly entrenched in the mind of the scientific world. Never before was it so thoroughly supported by such a wealth of compelling evidences which have multiplied with the progress of biological investigation. The scientific discussions are no longer regarding the occurrence of evolution. The fact of evolution is so widely recognized that it is regarded in the light of a great truth of nature. But, regarding the factors—the particular agencies that have been at work in nature to bring about this recognized development of life—there is much room for discussion. The attempt to designate the particular factor, or factors, has given rise to the different theories of organic evolution. That natural selection is an important agent at some stages of the process is commonly conceded, but the factors—more primary in nature—which produce variation and adaptation are more obscure and will for a long time be subjects of investigation.

## CHAPTER XIV

## SOME MISCELLANEOUS TOPICS. PAINLESS SURGERY, ETC.

No student of biology should be unacquainted with the circumstances leading up to the demonstration of the properties of anæsthetics and to painless surgery. The discovery of the methods of painless surgery was one of the greatest medico-biological advances of all time, and the application of these methods has conferred upon suffering humanity one of the greatest blessings of science. It was in a way a by-product of biological investigation, and one of those advances so intimately connected with the progress of biology that it is appropriate to consider it within the scope of this book.

The first definite step that brought anæsthetics into general use was the demonstration, in 1846, by W. T. G. Morton, that ether is a safe, effective and reliable agent for producing insensibility to pain during a surgical operation.

Since there were anticipations of this discovery and various claimants to recognition for the honor of the important achievements, the story should be told in

outline. Although the general use of anæsthetics in surgery dates from 1846, there are scattered references in classical writers, in mediæval literature and in other sources, to show that there was at least occasional employment of hemp, of mandrake and other opiates, to produce insensibility to pain during surgical treatment. Vapors of a certain kind of hemp were used in ancient times, Mandragora was used in the thirteenth century in Italy, and it is recorded that, in 1782, Augustus, King of Poland, underwent an amputation while rendered insensible by a narcotic. But these occurrences were incidental and led to no general use of pain-dispelling agents.

In 1787, Sir Humphrey Davy experimented upon himself with the effects of nitrous oxide, commonly called "laughing gas." His experiments were interesting, and although he did not inhale the gas to the point of complete insensibility, he made the suggestion that it might be useful in surgical practice.

Again, in 1818, Faraday observed the pain-dispelling effects of inhalation of the vapor of ether, and in 1822, 1833 and 1834 similar observations were reported by certain American physicians. But no practical outcome resulted. These observations appear "to have been regarded in the light of mere

scientific curiosities and subjects for lecture-room experiment." Had they been followed up by further experiments and demonstrations the advent of painless surgery would have been much earlier. They were vague foreshadowings of this important event.

The demonstration, the earliest use and the communication of the method of anæsthesia, is an American achievement. In 1844, Dr. Horace Wells of Hartford, Connecticut, experimented with nitrous oxide and began to use it for the painless extraction of teeth in his dental practice; but, owing to an unsuccessful experiment he became discouraged and did not follow the matter very far. He also experimented upon himself with ether but gave it up because he regarded its inhalation as too disagreeable.

Wells communicated his observations to the Boston dentist, Dr. W. T. G. Morton, who acted upon the suggestion with great enthusiasm and energy. Dr. Morton thought that sulphuric ether was probably a more promising agent than nitrous oxide gas and experimented with it extensively. After experiments on animals, and on patients in his dental practice, he became convinced of its reliability and, in September of 1846, he went to the Boston surgeon, Dr. J. G. Warren, and requested

opportunity to demonstrate his discovery on a patient about to undergo a severe surgical operation (removal of a tumor of the neck) at the Massachusetts General Hospital. In this case, the results of the administration of ether were satisfactory and this new method of painless surgery was communicated to the medical world. It was at first received with incredulity but speedily won recognition both in America and in Europe. Dr. Oliver Wendell Holmes supplied for the new method a singularly appropriate name, calling it anæsthesia, and the agents producing this insensibility to feeling, anæsthetics.

The honor of this achievement belongs to Dr. Morton (Fig. 27), but other claimants arose. The bitter controversy over priority and credit for the discovery was long drawn out. Dr. Charles T. Jackson, the chemist of Boston, made a determined effort to secure for himself credit for the discovery or, at least, equal recognition with Morton. His adherents got the matter considered by Congress and a committee of the House of Representatives voted him the credit. More judicious consideration of his claims leads to the conclusion that his connection with the discovery was incidental. It is true that he experimented with ether, and, not knowing that

Morton had already experimented with it, he suggested to Dr. Morton its pain-expelling effects. Apparently, there floated in Dr. Jackson's mind ideas regarding the employment of ether in surgery, but Morton took the further step of extensive experiment and use, and, above all, he demonstrated in the Massachusetts General Hospital that it was safe, effective and reliable. This brought it into general use.

Another man, Dr. Crawford Long, nearly anticipated the discovery of Morton. He was a practitioner in a small town of Georgia, and in March, 1842, he had placed a patient profoundly under the influence of ether and had painlessly removed a tumor from the neck. He had also used ether in other operations prior to 1846. In point of time he antedated Morton, but he had some misgivings as to whether it was the effect of the ether that produced insensibility, or a sort of hypnotic influence exerted by himself, and his results were not published till 1849.

Although Jackson had vaguely divined the possible utility of ether in surgery, and Long had used it in local country practice, it remained for Morton to carry the matter to a practical conclusion. It re-

mained for him, on the basis of his own experiments, followed by a hospital demonstration, to introduce the method of anæsthesia to the medical world. Morton's work was on a different plane from that of his predecessors. Except for its practical use by Long the work of others was merely anticipatory glimpses, and Morton, by demonstrating the safety and reliability of ether as an anæsthetic agent, introduced the method into surgery.

The new method was put into immediate use. In 1847, after ether had been successfully used in Europe, the Scottish surgeon, Sir James Simpson, introduced the use of chloroform which had been previously used in France by Flourens in experimentation on animals. Since that time the methods of administering ether and chloroform have been greatly improved and they remain to-day the chief agents used in anæsthesia.

**Vaccination—Edward Jenner.**—The method of vaccination for small-pox was an original and unique discovery, and antedated by more than three-fourths of a century, the modern vaccinations and serum inoculations devised by Pasteur.

Formerly, small-pox was a dreaded and highly contagious disease. It was very prevalent, sweeping

as an epidemic over communities and carrying terror and death in its path. Edward Jenner came from a dairy county—Gloucestershire—of England where a belief existed among the dairy people that persons who had contracted cow-pox were immune from small-pox. Cows are sometimes affected with a kind of disease accompanied by watery pustules on the udders, the hands of milkers become infected from these, and, after a mild sickness, those individuals were no longer susceptible to small-pox. It was the quality of sagacity in Jenner that led him to make use of this wide-spread belief and to investigate it with the trained mind and the powers of a scientific education. His discovery was a triumph of experimental science.

Edward Jenner, the discoverer (1749–1823) (Fig. 28) went to London at the age of twenty-one, in 1770, to pursue medical studies and came under the tutelage of the famous Dr. John Hunter. He was broadened by his contact with Hunter and by studies of comparative anatomy in his extensive museum. He attempted to interest Hunter in the question of immunity from small-pox, but Hunter, his preceptor, was too busily engaged with other matters to give it serious attention. Accordingly,

Jenner went to work on his own account to investigate the basis of the belief of the dairy people of his native county.

After some experimentation he devised means of vaccinating people with the relatively harmless virus of cow-pox. In 1796, he made inoculations with cow-pox material and after the recovery of his patients from a mild sickness, in two months, he inoculated the same individuals with small-pox matter but they remained unaffected. This convinced Jenner that this method was a protection against the contagion of small-pox, and two years after, in 1798, he announced his discovery to the world.

It was immediately put into use and Jenner was heralded as a great benefactor. Even before Jenner the voluntary inoculation with the virus of small-pox had been advocated. The disease was so prevalent and the chance to escape the contagion was so small that some were willing to run the risk of a voluntary inoculation, under the belief that these inoculations resulted in mild cases, but these were sometimes fatal.

Jenner, however, investigated the matter with scientific methods and devised a method of procuring

and using the virus of cow-pox so as to secure protection against the contagion of this most dreaded disease. At the present time the use of his method is so general—being at times prescribed by law—that small-pox, from being one of the most common diseases, is now comparatively rare.

The objections raised to vaccination are usually based on the fear of communicating other serious conditions. But this danger is reduced to a minimum by the production of pure and standard cultures.

## CHAPTER XV

## THE TEN FOREMOST MEN OF ZOÖLOGICAL HISTORY. THE RANK OF DIFFERENT NATIONS IN BIOLOGICAL PROGRESS

It is a popular pastime to make out lists of the foremost men in different lines of human achievement. In any subject it is natural to wish to settle the question, Who were the great path-breakers? It is a hazardous undertaking to attempt to designate any particular number, and it would be wrong to pretend, that there is an absolute standard upon which the ten men of greatest distinction can be selected. The formulation of such a tentative group, for zoölogy, if not taken too seriously, will serve some useful purpose. It will stimulate thought and direct attention to some of the most eminent men and to their contributions to zoölogical progress. The point of view adopted will lead to divergent results. Shall the foremost men be selected from the standpoint of wide influence, or from that of intellectual superiority of the individual and the quality of his work? The former basis would give a different group from the latter.

The list of ten men given below is based on the influence exerted by certain advances with which they were prominently connected, rather than merely on the high quality of their individual output as scientific investigators. In some cases the highest intellectual rank and the most eminent researches are combined in one individual of wide influence, in other instances, the influence of certain happy discoveries (as in the case of Mendel) are out of proportion to the relative rank of the man as a biologist.

**1. Harvey.**—Passing over Aristotle, who undoubtedly was the greatest scientific investigator of antiquity, and beginning with the revival of science in the sixteenth century, it seems to the writer that the pioneer work of Wm. Harvey (1578–1657) requires first recognition. He was at once observer and experimenter. The influence of his work on the circulation of the blood was profound and constructive. It not only gave for the first time a rational basis for the progress of physiology but also provided biological science with a new method and stimulated investigation. His book on the movement of the heart and the blood (*De Motu Cordis et Sanguinis*) published in 1628, is a biological classic. He also

made the first (after the Renaissance) independent advance in embryology (1651) and exercised considerable influence on the progress of morphology.

Although Vesalius (1514–1564) before Harvey had established the method of independent observation (human anatomy, 1543) he is subordinate to Harvey.

**2. Malpighi.**—Our second selection in chronological order is Malpighi (1628–1694). A careful observer, making progress in Minute Anatomy of animals, as in his famous monograph on the anatomy of the silkworm (1670), in the anatomy of plants (1671 and 1675), and, especially, in embryology (1672). He was the first also (in 1661) to see the actual circulation of blood in the capillaries. Through the exactness and the range of his observations, his spirit and his teaching of anatomy, he was directly connected with future progress.

Two of his contemporaries should be mentioned—Leeuwenhoek and Swammerdam. Leeuwenhoek was more discursive and less directly connected with progress. Swammerdam was more exact in his studies of insect anatomy, but the range of his work was more limited and the publication of his complete investigations was delayed till 1738. (During his

lifetime, a small volume on the general history of insects was published, in 1669.)

**3. Linnæus.**—From the standpoint of wide influence Linnæus (1707–1778) should be included in our list. He was the man who brought the present method of naming animals and plants into use and thereby gave to natural history a new language. He also introduced greater precision in the whole field of description and classification. The stimulus imparted to natural history by the work of Linnæus was immense. Collection and classification of animals and plants was carried on with enthusiasm and the knowledge of the animals of the globe rapidly extended. Linnæus also directed attention to species, and thereby served to lay the foundation for the question of the Origin of Species, which had such important connection in the work of Lamarck and Darwin.

**4. Cuvier.**—In the early years of the nineteenth century this French legislator and zoölogist gave a new direction to zoölogical study. While Linnæus had given a great impulse to natural history and to the study of the organism as a whole, Cuvier (1769–1832) started a strong movement for structural zoölogy. By extensive dissections he centered atten-

tion on the structure of animals and founded comparative anatomy. He also laid foundations of the science of Vertebrate Paleontology. On the whole, his influence on the progress of zoölogy was so extensive that he is to be heralded as one of the great path-breakers.

**5. Von Baer.**—One of the great intellects of the nineteenth century, von Baer (1792–1876), is to be remembered for the great service of founding in 1828 embryology on modern lines. This has proved to be one of the most helpful and illuminating lines of zoölogical investigation. This supplemented the work of Cuvier and from the two combined, comparative anatomy and embryology of animals, for many years proceeded the best results of zoölogical study.

**6. Johannes Müller.**—Johannes Müller (1801–1858) made physiology comparative, and stimulated researches in both physiology and morphology. Through his superb talents and extraordinary qualities as a leader he helped in a signal way to advance the standards of zoölogical investigation. By appointment a professor of physiology, he was also an investigator in zoölogical lines (morphology) and promoted exactness of observation and high quality of work. Considered strictly as a phys-

iologist his contributions were less eminent than those of Claude Bernard, but with a larger number of disciples and with unusual gift for stimulating and inspiring his students, he exerted a broad influence for progress.

**7. Pasteur.**—From all points of view there can be no doubt of the rank of Pasteur (1822–1895) as one of the greatest biologists of the nineteenth century. He is placed here as one of the men of greatest influence on the progress of zoölogy because zoölogy is the central subject of biology. There is continued growth in the sum total of his influence. In close relation with the influence of Pasteur should be mentioned the names of Koch and Lister.

**8. Darwin.**—Another, whose place is unquestioned in the rank of the foremost men of zoölogy, is Charles Darwin (1809–1882). His theory of natural selection as an agent of organic evolution has had the most stimulating effect upon zoölogical progress of any scientific advance. Although his predecessor, Lamarck, is accorded high place at the present day, no other man connected with the idea of organic evolution has exerted the wide influence of Charles Darwin.

**9. Max Schultze.**—This investigator embraced

in his work the summation of the protoplasm idea and the reform of the cell-theory. The effect of these two conceptions on zoölogy cannot be overestimated. Taking rank with the greatest discoveries of the nineteenth century, their direct application in zoölogy have been of supreme value. Schultze (1825–1874) also founded one of the most influencial periodicals of zoölogical science, the *Archiv für Mikroscopische Anatomie.*

**10. Mendel.**—Since 1900, the date of the rediscovery of alternative inheritance and purity of the germinal elements, Mendelian inheritance has been one of the most actively pursued of biological topics. Mendel (1822–1884) made his chief observations on plants and published the same in 1866–1867, but, the study of Mendelian inheritance in animal forms has exerted such a great influence, that his name is properly embraced in this list. On the basis of strictly scientific output and commanding intellectuality there are other names that would contest the position with Mendel, but, on the basis of the wide influence of his happy discoveries, he is entitled to rank with the men whose work has stimulated zoölogical investigations and been of the widest influence.

**Rank of the Nations in Biological (Zoölogical) Progress.**—The relative position of the different nationalities in biological progress from the zoölogical side is a question that offers ground for conflicting opinions. It is nevertheless of very great interest to students of zoölogy and is an appropriate matter for consideration in this connection. The general conclusion appears to me justified that no nation takes absolute preëminence in originality and in quality of investigation. Notwithstanding the brilliancy of the French, the deep philosophical contributions of the English, and the monumental industry of the Germans, not one of these nations can justly claim a position of undisputed supremacy.

The fact should not be overlooked that there have been notable pieces of zoölogical work from Italy, from Ramon y Cajal in Spain, from Russia and from the United States, but for the present inquiry, the matter is chiefly confied to the highly developed nations of Europe, the English, the French, and the Germans.

Let us first examine the part played by these three nations as path-breakers in the five outstanding biological advances of the nineteenth century.

The advance of greatest importance, the theory of

organic evolution, is to be credited in its inception to the French (Lamarck) and the English (Charles Darwin). This is probably the greatest philosophical contribution of the nineteenth century. After it was well under way it was taken up by scholars of different nationalities. Weismann, the German, De Vries, the Hollander, have made notable contributions, and, in America, Cope and others brought forward new aspects of Lamarckism and established the school of Neo-Lamarckism.

To the genius of Pasteur more than to any other worker we owe the basis of the germ-theory of disease with its concomitants as antitoxins, serum injections and vaccines. The Englishman, Lister, applied these to surgery and the German, Robert Koch, (a student of Ferdinand Cohn), established bacteriology (to which these matters belong) as an independent science.

The discovery of protoplasm is credited to the Frenchman Dujardin, but the great elaboration of the idea to Max Schultze, the German.

The cell-theory is a product of German scholarship—Schleiden and Schwann being founders and Schultze developer of this important conception.

In the experimental study of heredity, while the

work of Francis Galton, the Englishman, was of high quality and received earlier notice, it was overshadowed by the importance of Mendel's (Austrian) results.

The encouragement of research in the German universities—making results of investigations the basis of recognition and advancement in scholarly occupations—has had tremendous influence. The degrees conferred by German universities require the publication of a piece of research as a thesis, and if merely volume of output is considered, the Germans have been leaders—but for originality, quality and philosophical insight the French and the English take higher rank.

Turning from the outstanding advances we shall consider who have been path-breakers in some of the different divisions of zoölogical science—omitting the mention of the living and most recent personalities.

In Physiology, if the Germans have their Haller and Johannes Müller, so the English have their William Harvey and Burdon-Sanderson and the French their Magendie and Claude Bernard. The latter occupies a unique position. He was the veritable law-giver of experimental physiology. As an investigator probably he was as Howell has said,

"the greatest physiologist of all time." He is perhaps better compared with Ludwig than with Johannes Müller.

In Embryology while the Germans have Von Baer (Russian) as founder, the Italians have Malpighi, as forerunner, and the English have Francis M. Balfour, as developer.

In Comparative Anatomy the French have Cuvier, H. Milne-Edwards and Lacaze-Duthiers, the English, John Hunter, Richard Owen and Huxley to offset Meckel, Müller and Karl Gegenbaur.

The scientific output of a nation especially as to quality, is largely an expression of national temperament.

The French are remarkable for lucidity, for incisiveness, they are subtle and accurate in analysis and exhibit great originality.

In zoölogy, the English are notable for philosophical grasp (Darwin) and have a passion for intellectual honesty (Huxley).

The German mentality is more ponderous, less original, but has been guided by great industry, finding suggestions in the work of investigations of other nations and elaborating these suggestions with diligence and thoroughness. If other nations have

shown greater originality, and greater philosophical grasp in zoölogical fields, the Germans have been better developers of these new territories.

If we select the overshadowing contributions of Darwin and Pasteur we might be inclined to place English and French contributions to biological thought above those of the Germans. This is, however, a too restricted view, and, broadly considered, it appears that the different nations break about even as regards eminent contributions to biological progress. They constitute an international group of peers among whom it is invidious to make distinctions.

The fact that German contributions to scholarship have been more energetically advertised and are therefore more widely known, has given rise to a wide-spread opinion that the Germans have been unquestioned leaders in biological progress. But, this general impression gives way under a candid consideration of the quality and the importance of the scholarly output of other nations.

**Zoölogy and Intellectual Progress.**—Undoubtedly the progress of zoölogy has played an important part in the intellectual development of civilized mankind, but the reason for this is only vaguely

understood. That the progress of science, broadly speaking, has been beneficial will not be disputed. Manifestly it has been a powerful reconstructing force. Wherever investigations of the phenomena of nature have taken away old beliefs they have substituted something better and more consistent. But zoölogy in particular, in the last half century, has concerned itself with the investigation of the phenomona of all living animals of the globe. This has brought zoölogical investigation into a realm that touches more closely than any other, the problems of human origin and destiny.

The phenomona of life are so difficult of analysis and apparently so mysterious that, naturally, there was a great amount of metaphysical speculation regarding their interpretation, and many superstitions and misconceptions arose. Zoölogy undertook to investigate these problems and came into conflict with traditional opinion. The atmosphere of thought engendered by the progress of these studies of animal life was broadening, and in its influence as wholesome as it was stimulating. Wherever biological investigation prospered the results shed light and dispelled error. There was progress in straight thinking.

Immediately after the Renaissance these new

ideas began expanding the horizon of thought and provoked many controversies, which for the time were often bitter, but, in many instances, resulted in freeing the mind from the bonds of inherited and traditional superstitions.

Gradually all animal life came to be looked on as the result of an orderly progress with no place for the idea of chance. The idea of the constancy of nature was established. Then arrived, in the last half of the nineteenth century, largely as the result of zoölogical progress, the doctrine of organic evolution which produced a mental revolution. It is generally recognized that from the time of the revival of scientific learning to the present, while all scientific study was making towards enlightenment, still, the investigation of problems involving animal life had unusually broad influence in promoting intellectual progress.

The controversies engendered were often against theological opinion, but these flashes of enlightenment were by no means confined to that territory. Scientific dogma (as that of the fixity of species) and medical tradition (as to the source and the nature of disease) also gave way to investigations of a biological character.

## CHAPTER XVI

## SOME USEFUL BOOKS

THE books and periodical articles in the field of zoölogy are so numerous and cover such a wide range of topics that some sort of guide to the best reading is nearly indispensable.

A continually increasing number of persons take an interest in the larger ideas that have developed from the critical investigation of animals, and this class of readers often seek for palatable and satisfying literature on zoölogical subjects.

The writings appeal to various kinds of interest—there are the more popular and the more technical. In selecting reading we must recognize that references which are good for one purpose often are not good for another. Moreover, the focus of interest of the reader varies with his mood as well as with his purpose, and the selection of suitable reading for different needs is a matter of no little difficulty.

There are informing books about insects, birds and protozoa, but these will not be specifically adapted to one whose chief interests are in evolution or genetics.

The more technical publications are standardized and are less difficult to indicate than good sources of a popular character. For one whose interest in the results of zoölogical studies is beginning to grow, it is a great assistance to have some references to reliable and trustworthy literature for fire-side reading, in addition to the books of general reference which will be consulted only at intervals.

There are books that supply stimulus and promote a feeling for the work of the naturalist, such as Darwin's *Voyage of the Beagle*, Bates's *A Naturalist on The River Amazon*, Wallace's *Malay Archipelago* and those writings that bring us into contact with great personalities such as the biographies of Darwin, Pasteur, Huxley and Lister.

In the references indicated below attention has been given to selecting sources of unquestioned merit and reliability, but no claim is made to giving a balanced list of reading. Assuming that a more general interest exists in historical phases and in biographies, I have cited a relatively larger number of references of that nature.

The object of the reading lists is to supply—not in too great number—reliable and trustworthy references to a variety of zoölogical subjects. The more

advanced student who has need of zoölogical references on subjects not included will know how to go about finding them. The general reader will also find additional biographical sketches as well as general topics referred to in the indices of the periodical literature with which nearly all libraries are provided.

It has seemed desirable to give, first, a suggested list of fifty books for the nucleus of a reference library, and to follow this list with additional titles of books and articles in which the reader may find food for various kinds of internal hunger which he may feel from time to time for supplementary reading.

# READING LISTS OF BOOKS AND PERIODICAL ARTICLES ON ZOÖLOGICAL SUBJECTS

## (A) A REFERENCE LIBRARY OF FIFTY BOOKS

A suggested reference library of fifty titles including, besides manuals and text-books, books on special topics of zoölogical science. Among these special topics are biographies, historical phases, evolution, genetics, heredity, cytology, ecology, birds, insects, protozoa, etc. The books are arranged according to topics and not in the order of preference.

HERTWIG, RICHARD. *A Manual of Zoölogy*, translated and edited by J. S. Kingsley, 1902. Revised edition, 1912. This is a standard reference, or PARKER and HASWELL'S *Text-Book of Zoölogy*, 2 vols., 2nd edition, 1910, or THOMSON'S *Outlines of Zoölogy*, 3rd edition, 1899.

WIEDERSHEIM, ROBERT. *Comparative Anatomy of Vertebrates*, translated by W. N. Parker, 3rd edition, 1907.

MORGAN, THOMAS H. *Experimental Zoölogy*, 1907.

DARWIN, CHARLES R. *A Naturalist's Voyage Round the World.* New edition, 1880. Also published under the title *The Voyage of the Beagle.*

DARWIN, CHARLES R. *The Origin of Species*, 1859. Many subsequent editions.

PACKARD, A. S. *Lamarck, The Founder of Evolution, His Life and Work*, 1901.

WEISMANN, AUGUST. *The Evolution Theory*, translated by J. A. and Margaret Thomson, 2 vols., 1904.

DE VRIES, HUGO. *Species and Varieties, their Origin by Mutation*, 1905.

ROMANES, GEORGE J. *Darwin and After Darwin*, Vol. I, 1895. Or WALLACE, ALFRED R., *Darwinism*, 1889.

KELLOGG, VERNON L. *Darwinism To-day*, 1907.

JUDD, JOHN W. *The Coming of Evolution*, 1910.

JORDAN, DAVID S., and KELLOGG, VERNON. *Evolution and Animal Life*, 1907.

LULL, R. S. *Organic Evolution*, 1917.

HUXLEY, T. H. *Man's Place in Nature*, in his Collected Essays, 1900. Also published in many forms.

OSBORN, HENRY F. *Men of the Old Stone Age*, 1916.

FOSTER, MICHAEL. *Lectures on the History of Physiology During the 16th, 17th, and 18th Centuries*, 1901.

THOMSON, J. ARTHUR. *The Science of Life, An Outline of the History of Biology and Its Recent Advances*, 1899.

LOCY, WILLIAM A. *Biology and Its Makers*, 3rd edition, 1915. Historical phases.

DARWIN, F. *Life and Letters of Charles Darwin*, 2 vols., 1887.

HUXLEY, LEONARD. *Life and Letters of Thomas Henry Huxley*, 2 vols., 1901.

FRANKLAND, PERCY and G. *Pasteur*, 1901.

PAGET, STEPHEN. *Pasteur and After Pasteur*, 1914.

WRENCH, G. T. *Lord Lister, His Life and Work*, 1913.

KELLY, HOWARD A. *Walter Reed and Yellow Fever*, 1906.

SEDGWICK, WILLIAM T., and WILSON, EDMUND B. *General Biology*. revised edition, 1895.

DARWIN, CHARLES. *Formation of Vegetable Mould through the action of Worms*, 1881.

WILSON, EDMUND B. *The Cell in Development and Inheritance*, 1896.

WALTER, H. E. *Genetics*, 1913.

CONKLIN, E. G. *Heredity and Environment in the Development of Men*, 1915.

DAVENPORT, CHAS. B. *Heredity in Relation to Eugenics*, 1911.

BATESON, W. *Mendel's Principles of Heredity*, with translations of his original papers on hybridization, 1902.

PUNNETT, R. C. *Mendelism*, 1911.

SHELFORD, VICTOR E. *Animal Communities in Temperate America*, 1913.

CHAPMAN, FRANK M. *Bird-Life*, 1899.

BARROWS, WALTER B. *Michigan Bird Life*, Lansing, Michigan, 1912.

COMSTOCK, JOHN H., and BOTSFORD, ANNA. *A Manual for the Study of Insects*, 2nd Edition, 1899.

HOLLAND, W. J. *The Butterfly Book*, 1898.

FABRE, J. H. *The Hunting Wasps*, 1913.

HUXLEY, T. H. *The Crayfish—An Introduction to Zoölogy*, 1881, also 1906.

BAILY, F. R., and MILLER, A. M. *Text-Book of Embryology*, 3rd edition, 1916.

LILLIE, F. R. *The Development of the Chick*, 1908.

CALKINS, G. N. *The Protozoa*, 1901. Also, *Protozoölogy*, 1909.

JORDAN, DAVID S. *A Manual of Vertebrates*, new edition, 1916.

PRATT, HENRY S. *A Manual of Common Invertebrate Animals*—exclusive of insects, 1916.

HUXLEY, T. H. *Lessons in Elementary Physiology*, edited and revised by Joseph Bancroft, 1915, or MARTIN, H. N., *The Human Body*, new edition, 1917.

HERRICK, C. J. *An Introduction to Neurology*, 1916.

VERWORN, MAX. *General Physiology*, translated by Frederick S. Lee, 1899.

THOMSON, J. ARTHUR. *The Study of Animal Life*, 1892.

MARSHALL, J. MILNES. *The Frog*, new edition, 1916, or HOLMES, *Biology of the Frog*, 1906.

BEDDARD, P. E. *A Text-Book of Zoögeography*, 1895.

## (B) SUPPLEMENTARY LISTS OF BOOKS AND PERIODICAL ARTICLES

Embracing: (1) History and Biography; (2) Manuals and Text-Books on Zoölogy; (3) Comparative Anatomy, Embryology, etc.; (4) Books on special topics and (5) Miscellaneous.

### (1) History and Biography

#### (a) *History*

Carus, Victor. *Geschichte der Zoölogie*, 1872. Also *Histoire de la Zoölogie*, 1880. A work of scholarship.

Cuvier, Georges. *Histoire des Sciences Naturelles*, 5 vols., 1841–1845. Excellent. Written from an examination of the original documents.

Foster, Michael. *Lectures on the History of Physiology*, 1901. Fascinatingly written. Notable for poise and judicial estimates, based on the use of the original documents.

Geddes, P. "A Synthetic Outline of the History of Biology." *Proc. Roy. Soc. Edinb.*, 1885–1886.

Hertwig, Oskar. "The Growth of Biology in the Nineteenth Century." *Ann. Rept. Smithson. Inst.*, 1900.

Lankester, E. Ray. "The History and Scope of Zoölogy," in *The Advancement of Science*, 1890. Same article in the *Ency. Brit.* Tenth edition.

Libby, Walter. *An Introduction to the History of Science*, 1917. A small excellently written treatise, general in scope.

Locy, William A. Article "Zoölogy," *Cyclopædia of Education*, 1913. Also *Biology and Its Makers*. See list of fifty books.

MEDICINE. Related topics, dealing with the history of anatomy, embryology, physiology, etc., are treated in the various Histories of Medicine.

MERZ. *A History of European Thought in the Nineteenth Century*, vol. II, *Scientific Thought*, 1903.

MIALL, L. C. *The Early Naturalists—Their Lives and Work* (1530–1789), 1912. Good.

OSBORN, HENRY F. *From the Greeks to Darwin*, 1894. For other references to the history of evolution see below, under evolution.

THOMSON, J. ARTHUR. *The Science of Life*. See list of fifty books.

WALSH, J. J. *The Popes and Science*, 1908.

WHITE, ANDREW, J. *A History of the Warfare of Science with Theology in Christendom*, 2 vols., 1900. For Vesalius and the overthrow of authority in science, etc.

WILLIAMS, HENRY SMITH. *A History of Science*, 5 vols., 1904. Also *The Story of Nineteenth Century Science*, 1900. Good portraits.

(b) *Biography*

**General Reference.** RICHARDSON, B. W. *Disciples of Æsculapius*, 2 vols., 1901. Collected papers from the Asclepiad, containing accounts with portraits of Harvey, J. Hunter, Malpighi, Vesalius and others.

**Agassiz, Louis.** *Life and Correspondence*, by his wife, 2 vols., 1885. *Life, Letters and Works*, Marcou, 2 vols., 1896. "Agassiz at Penikese," *Amer. Nat.*, 1898. "What we Owe to Agassiz," Wilder, *Pop. Sci. Mo.*, July, 1907.

**Aristotle.** CUVIER on, a panegyric. GEORGE H. LEWES, *Aristotle—A Chapter from the History of Science*, 1864, a critical study. HUXLEY, *On some Mistakes attributed to Aristotle*.

**Balfour, F. M.** M. Foster, in *Nature*, vol. 29, 1882. Also, Life with portrait in the Memorial Edition of Balfour's Works. Osborn, Recollections, with portrait, *Science*, vol. 2, 1883. Waldeyer, *Archiv für Mikr. Anat.*, 1882.

**Baer, Karl E. von.** *Leben und Schriften*, his autobiography, 1864, 2nd edition, 1886. *Life* by Steida, 1886. Obituary, *Proceed. Roy. Soc. Lond.*, 1878. *Nature*, vol. 15, Hæckel, *The History of Creation*, vol. I, 1884. Locy, "Von Baer and the Rise of Embryology," *Pop. Sci. Mo.*, 1905. *Rev. Scient.*, 1879. Fine portrait, as a young man, in *Harper's Magazine* for 1899.

**Bernard, Claude.** *Life* by Michael Foster. Excellent.

**Bichat, François X.** *The Practioner*, vol. 56, 1896.

**Bois-Reymond, Emil Du.** See Reymond.

**Boveri, Theodor.** Sketch in *Science* by Richard Goldschmidt, Feb. 25, 1915.

**Brooks, William K.** Conklin, J. *Hop. Univ. Circulars. The Century*, vol. 25. A sketch of his life by some of his former students and associates, three portraits, *Jour. Exp. Zoöl.*, vol. 9, 1910.

**Burdon-Sanderson.** *Nature*, vol. 73, 1905–06. A memoir, *Nature*, vol. 89, 1912.

**Cajal, Ramon y.** See Ramon y Cajal.

**Cohn, Ferdinand.** *Blätter der Erinnerung*, with portrait, 1898.

**Cope, E. D.** "A Great Naturalist," H. F. Osborn in *The Century*, vol. 33, 1897. Gill, "Edward Drinker Cope, Naturalist," *Amer. Naturalist*, 1897. Sketches of, *Amer. Journ. Sci.*, vol. 157, 1899. *Nature*, vol. 59, 1898–99. *Pop. Sci. Mo.*, vol. 13, 1878. *Ibid.*, vol. 19, 1881; *Science*, vol. 9, 1899. Obituary Notice, with portraits, *Amer. Naturalist*, 1897.

**Cuvier, Georges.** *Life* by Flourens. *Memoires* by Mrs.

LEE, 1833. BUCKLE, *History of Civilization*, vol. I, pp. 633, et seq. LOCY, *Biology and Its Makers*, Chapter VII.

**Darwin, Erasmus.** KRAUSE'S *Life of E. Darwin*, translated into English, 1879. PACKARD, *Life of Lamarck*, chapter XIV.

**Darwin, Charles R.** *Life and Letters* by his Son, 2 vols., new edition, 1896. *More Letters of Charles Darwin*, 2 vols., 1903. Chapter in MARSHALL'S *Lectures on the Darwinian Theory*. POULTON, *Charles Darwin and the Theory of Natural Selection*, 1896. The original communications of Darwin and Wallace, with letter of transmissal signed by Lyell and Hooker, published in the *Trans. Linnæan Soc.*, 1858, were reprinted in the *Pop. Sci. Mo.*, Oct. 11, 1912.

**Dohrn, Anton.** BOVERI in *Science*, Oct. 11, 1912. *Pop. Sci. Mo.*, vol. 66, p. 99, portrait.

**Dujardin, Félix.** Notice Biographique by JOUBIN, with portraits and illustrations, *Archives de Parasitol*, vol. 4, 1901. Dujardin's original description of Sarcode, *Ann. des Sci. Nat.* (*Botanique*), vol. 4, p. 367, 1835.

**Duthiers.** See Lacaze-Duthiers.

**Edwards.** See Milne-Edwards.

**Ehrenberg, Christian G.** *Life* by LAUE, 1895. KENT, *Manual of Infusoria*, vol. I.

**Fabre, J. H.** LEGROS, FABRE, *Poet of Science*, 1917. MAETERLINCK, in Introduction to Fabre's *Life of the Spider*. ELEANOR VAN HORN, *American Magazine*, 1907. *Literary Digest*, 1907.

**Foster, Michael.** *Nature*, vol. 75, 1907, p. 345.

**Galton, Francis.** *Memories of my Life*, 1908. Sketches of, *Pop. Sci. Mo.*, vol. 29, 1886, *Nature*, vol. 70, 1907.

**Gegenbaur, Karl.** *Erlebtes und Erstrebtest*, portrait, 1901.

*Anat. Anzeiger*, vol. 23, 1903. *Ann. Rept. Smithson. Inst.*, 1904.

**Gesner, Conrad.** BROOKS in *Pop. Sci. Mo.*, 1885, illustrations.

**Hæckel, Ernst.** *His Life and Work* by BÖLSCHE, 1906.

**Harvey, William.** FOSTER, *Lectures on the Hist. of Physiology*, Lecture II, Excellent. DALTON, *History of the Circulation*. HUXLEY, *William Harvey, a critical essay*. Life by D'ARCY POWER, 1898. BROOKS, "Harvey as Embryologist," *Bull. Johns Hop. Hospital*, vol. 8, 1897. Good. MORETON, *An Anatomical Dissertation upon the Movement of the Heart and Blood in Animals*, a facsimile reproduction of the first edition of the famous *De Motu Cordis et Sanguinis*, 1628, with English translation, 1894. *Life* by WILLIS in *The Works of Harvey rendered into English*, Sydenham Soc., 1847.

**His, Wilhelm.** F. P. MALL in *Amer. Journ. Anatomy*, vol. 4, 1905. Sketch *Anat. Anzeiger*, vol. 26, 1904.

**Hunter, John.** *The Scientific Works of J. Hunter*, 2 vols., 1861. RICHARDSON, *Disciples of Æsculapius*, vol. 1, 1901.

**Huxley, T. H.** *Life and Letters*, by his son, 1901. Numerous Sketches at the time of his death, 1895. See *Nature*, *Pop. Sci. Mo.*, *Nineteenth Century*, *etc.*

**Jenner, Edward.** CAMAC, *Epoch-Making Contributions to Medicine, Surgery and the Allied Sciences*, 1909.

**Koch, Robert.** *Pop. Sci. Mo.*, vol. 36, 1889. *Review of Reviews*, vol. 2, 1890. *Ann. Rept. Smithson. Inst.*, 1911, p. 651, with portrait. Sketches and references to his discoveries numerous.

**Kölliker, Albrecht von.** His Autobiography, *Erinnerungen aus Meinem Leben*, 1899, several portraits. WELDON, "Life and Works," *Nature*, vol. 58, with fine portrait. STERLING, *Ann. Rept. Smithson. Inst.*, 1902.

**Lacaze-Duthiers, Henri de.** Life with portraits in *Archives de Zoöl. Expériment*, vol. 10, 1902.

**Lamarck, H. B.** A. S. PACKARD, *Lamarck, the Founder of Evolution*, 1901. The best single reference on Lamarck.

**Leidy, Joseph.** *Nature*, vol. 44. *Pop. Sci. Mo.*, vol. 28, 1891. A Tribute by A. S. Minot, *Science*, 1913. His University Career, by W. Hunt, 1892.

**Leuckart, Rudolph.** *Archives de Parasitol.*, vol. 1, no. 2. *Nature*, 1898.

**Leeuwenhoek, Antony van.** New biographical facts in RICHARDSON, *Disciples of Æsculapius*, vol. 1, p. 108. LOCY, *Pop. Sci. Mo.*, April, 1901.

**Leydig, Franz.** Brief sketch in his *Horae Zoölogicae*, 1902. Also in MIALL and DENNEY, *The Cockroach*, 1886.

**Linnæus, Carolus.** CADDY, *Through the Fields with Linnæus*, 1887. "Jubilee at Upsala," *Science*, April 26, 1907. Many sketches and references in periodical literature in 1907—the two hundredth anniversary of his birth.

**Lister, Joseph.** WRENCH, G. T., *Lord Lister, His Life and Work*, 1913. *Pop. Sci. Mo.*, vol. 52, 1898. *Rev. of Reviews*, vol. 14, 1896. Celebration of Lister's 80th birthday, *Pop. Sci. Mo.*, 1907.

**Ludwig, Carl.** BURDON-SANDERSON, "Ludwig and Modern Physiology," *Ann. Rept. Smithson. Inst.*, 1896. LOMBARD, W. P., "The Life and Work of Carl Ludwig," *Science*, Sept. 15, 1916.

**Mall, Franklin P.** HUBER, In Memoriam, *Anat. Record*, Jan. 1918; Flexner, An Appreciation, Sabin, Scientific Achievements, *Science*, March 15, 1918.

**Malpighi, Marcello.** RICHARDSON, Vol. II. ATTI, *Life and Works*, in Italian, 1847. *Marcello Malpighi e l'Opera Sua*, 1897—a collection of addresses at the unveiling

of Malpighi's statue at Crevalcuore, that by Kölliker excellent. Locy, "Malpighi, Swammerdam and Leeuwenhoek," *Pop. Sci. Mo.*, 1901. MacCallum, *J. Hop. Univ. Hospit. Bull.*

**Mendel, Gregor.** Bateson, W., *Mendel's Principles of Heredity*, 1902, also 1904. Contains biographical notice and translation of the original papers on hybridization. *Ann. Rept. Smithson. Inst.*, 1901–1902. *Pop. Sci. Mo.*, vol. 62, 1903; vol. 63, 1904. *Science*, vol. 23, 1903.

**Milne-Edwards, H.** Biographical sketch in *Ann. Rept. Smithson. Inst.* for 1913.

**Minot, C. S.** Notice by H, H. Donaldson, *Science*, Dec. 25, 1914; by C. W. Eliot, *Science*, May 14, 1915. F. T. Lewis, with portrait.

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